POWER

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PERTINENT QUESTIONS

If you are not able to answer these and similar questions you should take steps to equip yourself to do so before you have occasion to regret it.

ARE you, as engineer of your plant, commanding a salary equal to or more than the plumber, steamfitter, or other mechanic with whom you are familiar; not salary per month, but per hour?

Are you familiar with different appliances which are coming on the market, and into your plant all the time, or does your employer send for a consulting engineer to tell him how to install a boiler or an engine and what the sizes should be?

Does he send for an electrician when a new motor is to be installed, or does he ask you the size, voltage, etc., and are you able to answer him without hesitation and tell him intelligently just what the needs of the plant are and how they should be handled?

Can you cut a coil out of an armature and keep the plant running until a permanent repair is made?

Are you pestering your employer continually about the little things which are going wrong about the plant, or are you keeping things going so smoothly that he leaves all the small things to your best judgment, without keeping the worry of the power plant on his mind?

Are you keeping things about the plant as well as yourself clean, or does the boss pick his way through the filth in your department when he comes to see you?

Do you keep your catalogs and copies of your trade papers filed and do you read them, so that you are familiar with the troubles which may befall you and the appliances which can help you in your work?

If your employer should tell you that a state law had been passed requiring all steam boilers when used in a battery to have stop and check valves on their outlets, could you tell him why they should be installed and could you show him how they operate?

Are you able to turn to some book or paper and show the construction as well as the great advantages of this particular kind of a valve?

Can you tell the difference between a gate valve and a globe valve, and where each should be used?

If the superintendent should tell you that he was going to buy current from a central station, and shut down the power plant, could you show him where the company would lose money; and when he started to tell you about three-phase, 25-cycle, alternating-current synchronous motors, could you understand and explain to him just what each term meant?

If you are not able to answer these questions either you do not supply yourself with the means to learn or do not use them. In either case you should mend your ways. Then put some of the things you learn into effect in your plant. Perhaps you are not interested in your work; if you aren't, get out and do something you are interested in and quit robbing the man who is paying you for something he doesn't get.

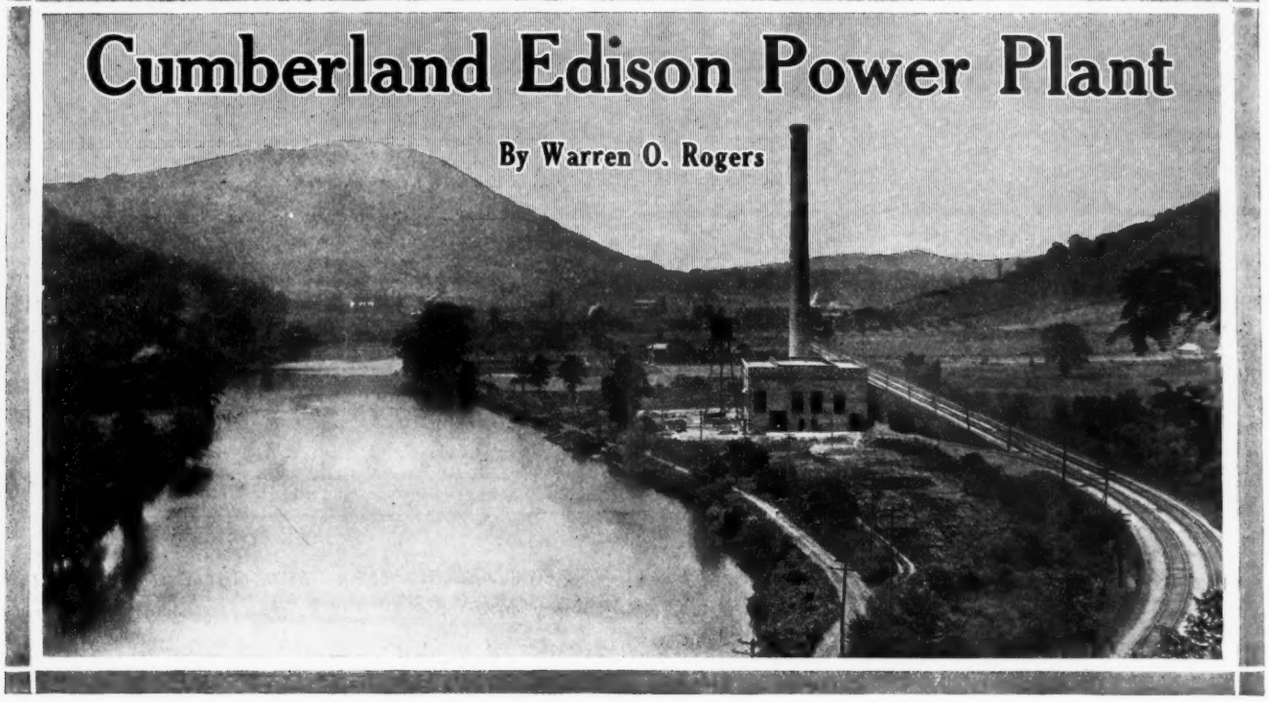
Don't try to make excuses by saying your employer won't buy this or that, which you want. If he won't, it is probably because you haven't shown him where it would pay him to do so. Every engineer has worked for some pretty tight-fisted employers, but when they were told and shown where certain appliances would save them money, they were generally the best buyers.

Don't get peeved if you can't get what you want on the start, but keep everlastingly at it, and if you use your mind as well as your body, you will soon get the money for your work, and will have a plant that is a satisfaction to yourself as well as to your employer.

[Contributed by Schuyler T. Hooper, Kansas City, Mo.]

Cumberland Edison Power Plant

By Warren O. Rogers



SYNOPSIS—In designing this plant the turbine foundations that now carry 2,000-kw. turbo-generators have been built to accommodate units of 4,000-kw. capacity, thus providing for future increased output. The plant apparatus is arranged on the unit system, two 522-hp. boilers serving one 2,500-kv.-a. turbine. A novel method of handling the coal from the coal pile to the stoker hopper is employed, using two traveling-bucket conveyors that operate on an industrial track in front of the boilers. They cost about $1,500 and do away with an expensive coal bin and conveying system that would otherwise be necessary and that would cost about $22,000.

The old central station of the Edison Electric Illuminating Co., Cumberland, Md., was the third one in the country to engage in the commercial distribution of electric energy. Its situation in the business section of the city, although central for reaching its customers, was away from the Potomac River and where coal, if used as a fuel, would have to be carted from the railroad siding to the plant. The city is in the natural-gas region, and gas of 900 B.t.u. per cu.ft. is used in the boiler furnaces, because it is about 20 per cent. cheaper, under existing conditions, than coal containing 14,500 B.t.u. per lb.

The City of Cumberland (about 30,000 population) is in the Georges Creek coal region, and there is an area of about 20 by 30 mi. in which there are many mines and towns to which electric energy could be supplied if the power plant was of sufficient capacity. The coal mines in this section have about worked out the thick veins, and as the workings go deeper electric energy will be needed to operate the shafts for haulage, pumping and other mine work; slopes are used mostly with the upper seams.

Owing to the old power house being taxed to its capacity, the constantly growing load and the opportunity for obtaining new business in the surrounding territory, it was decided to construct a new modern plant. This work has been done by the Electric Development Co., of Cumberland, Md., George A. Eyler, president, who designed and supervised the construction of the new station described and illustrated herewith.

Power-Plant Site and Construction

Although the new plant is outside of the city, the site is ideal in several respects. There is plenty of room for enlarging the station should it become desirable, coal can be unloaded from railroad cars at the plant, and an abundant supply of cold condensing water is obtainable from the Potomac River, close at hand. The turbine and boilers are housed under one roof, with a dividing wall running lengthwise of the building between

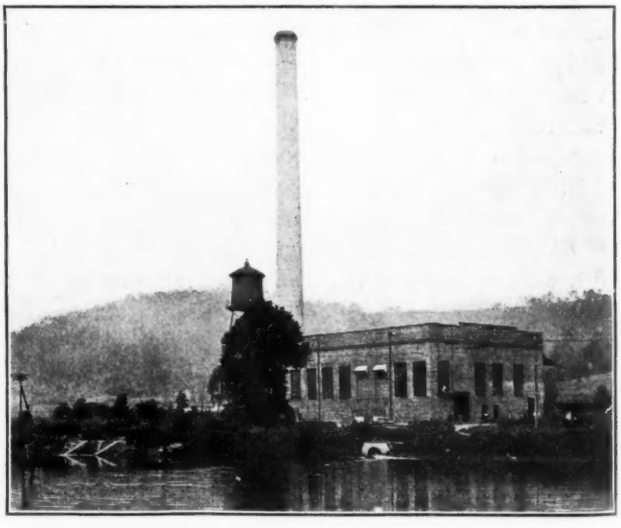


FIG. 1. POWER PLANT AND RIVER IN FOREGROUND

them. The building is as nearly fireproof as it is possible to construct it, and the superstructure is of steel self-supporting curtain construction, with the columns at 16-ft. centers. The roof is of 1½-in. reinforced-concrete slabs, self-supported by 6-in. side beams and purlin and Barrett's specification roofing. The building, Fig. 1, is 138 ft. long, 86 ft. wide and 42 ft. high. The wall separating the turbines from the boilers is central of the building.

Six 522-hp. water-tube boilers, each containing 5,220 sq.ft. of heating surface, are in the boiler room, Fig. 2, and are placed with the rear end toward the turbine room, but allowing for an 8-ft. alley that provides ample room for working on the rear end while cleaning or making repairs. There are a 14-ft. firing aisle and an industrial track in front of the boilers.

Each furnace is equipped with a five-retort mechanical stoker, driven by two 5¼x6-in. vertical engines by means of a chain drive. The engines are belted to a shaft running in a concrete duct that extends along the boiler fronts below the floor line. The stokers are driven from this shaft. Each engine is capable of driving all of the stokers and is arranged with a clutch for engaging or disengaging it with the stoker driving shaft.

FIG. 2. BOILER ROOM AND TRAVELING-BUCKET CONVEYOR AT FAR END

Forced draft is provided by two engine-driven fans that occupy the space at the right of the plan view, Fig. 4. The speed of the fan and stoker engines is automatically regulated. The draft and the stoker feed are thus hastened or retarded in unison, according to the steam pressure in the boiler and the air pressure in the air ducts connecting with the under side of the stokers.

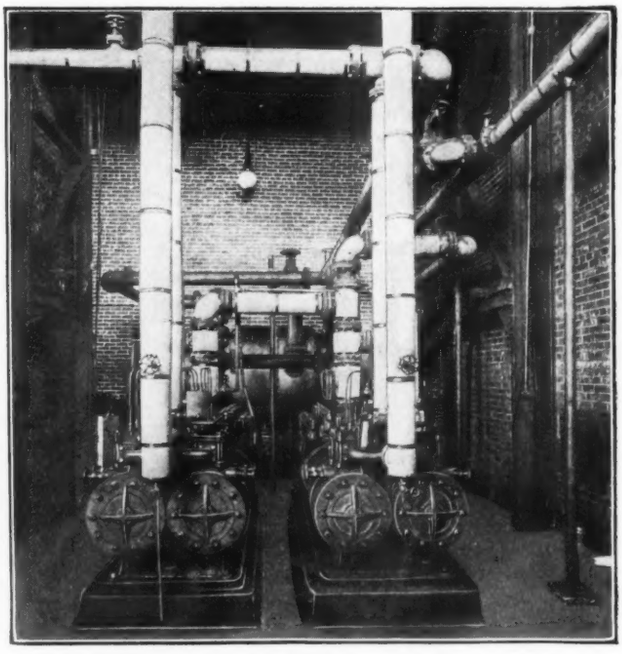


FIG. 3. TWO FEED PUMPS BETWEEN BOILER SETTINGS

The boilers are set in batteries of two, and sufficient space has been provided between the first two batteries for the two 12&8x12-in. pot-valve outside-packed duplex boiler-feed pumps, Fig. 3. The suction lines are 6 in. diameter and are cross-connected above the pumps, as are also the 5-in. discharge lines. The exhaust steam from these pumps goes to a feed-water heater placed at their rear.

This heater is of the closed type and operates the same as a surface condenser. An advantage of this heater is that it takes the same size of tube as the condensers, which permits of the condenser tubes being used in the heater if repairs are necessary. The water from the hotwell is forced by the feed pumps through the tubes on its way to the boilers. Exhaust steam from the pumps and other auxiliaries about the plant fills the space around the tubes. When the amount of exhaust steam is excessive, the water goes to the boilers within a few degrees of the temperature of the exhaust steam. When the steam supply is limited, the heater condenses the steam and transfers its latent heat to the water.

The feed water has two sources of reaching the boilers. One is through a 5-in. header that runs along the front end and above the boilers. A 3-in. branch is piped to each boiler. The other is a 3-in. connection to the 3-in. blowoff line, that is in a concrete trench at the rear of the boilers. This gives a secondary method of supplying the boilers with feed water in case anything goes wrong with the main supply line. The general arrangement of these units is shown in the plan view, Fig. 4, and the elevation in Fig. 5.

Makeup water is supplied by two motor-driven hotwell and tank pumps that run at 1,800 r.p.m. It is delivered to the heater after passing through a V-notch meter having a capacity of 100,000 lb. of water per hour. The water used for boiler feeding also passes through this meter, so that a record is had of all water used by the boilers. All water going to the boilers is metered by a venturi meter in the discharge line of

the pumps. The V-notch meter and the two motor-driven pumps are in the turbine room (Fig. 6), and all rest on concrete foundations.

A 6-in. line also runs from the feed pumps to a 30,000-gal. capacity wooden tank in the yard, supported by a structural steel tower. This tank supplies water for priming the pumps and for fire protection.

In the boiler room the furnace gases pass to a main smoke breeching that extends along the rear end above the boiler to the chimney on the outside of the building. This breeching is 6 ft. 3 in. wide and 16 ft. 9 in. high, having an area of 104.6 sq.ft. The chimney has a red-brick octagonal base for a height of 40 ft., above which it is radial brick to a height of 225 ft. It has an internal diameter of 11 ft. at the top and weighs 740 tons.

The arrangement for handling the coal is out of the ordinary, has greatly cut the first cost of installation and should be operated at a low labor cost. Coal is delivered to the plant on a siding from the main line of the Baltimore & Ohio Railroad. The spur track terminates in a concrete trestle elevated 9 ft. above the boiler-room floor.

This gives a normal coal-storage capacity under the trestle of 150 tons. A concrete bottom sloping toward the boiler room assists in moving the coal forward as it is used. The wall in front of the boilers is fitted with metal curtains (Fig. 2), which can be rolled to any height according to the stage of the coal pile. It would require too much work for a fireman to shovel from the coal pile into the stokers, but Mr. Eyler avoided this and the necessity of an expensive overhead coal bin and conveying system that would have cost about $22,000, by putting in front of the boilers, an industrial track on which two small motor-operated traveling bucket conveyors run. The coal passer moves either of the conveyors in front of the stoker requiring fuel and, starting the bucket, shovels the coal into the hopper of the conveyor, which delivers it to the stoker hopper. The operation is repeated at the various stokers as the fuel supply requires replenishing. This method of handling the coal from the storage to the stokers requires the labor of one man per watch. Each conveyor cost about $750. In a plant of this capacity it would seem that the coal-handling problem has been worked out to a simple and economical conclusion.

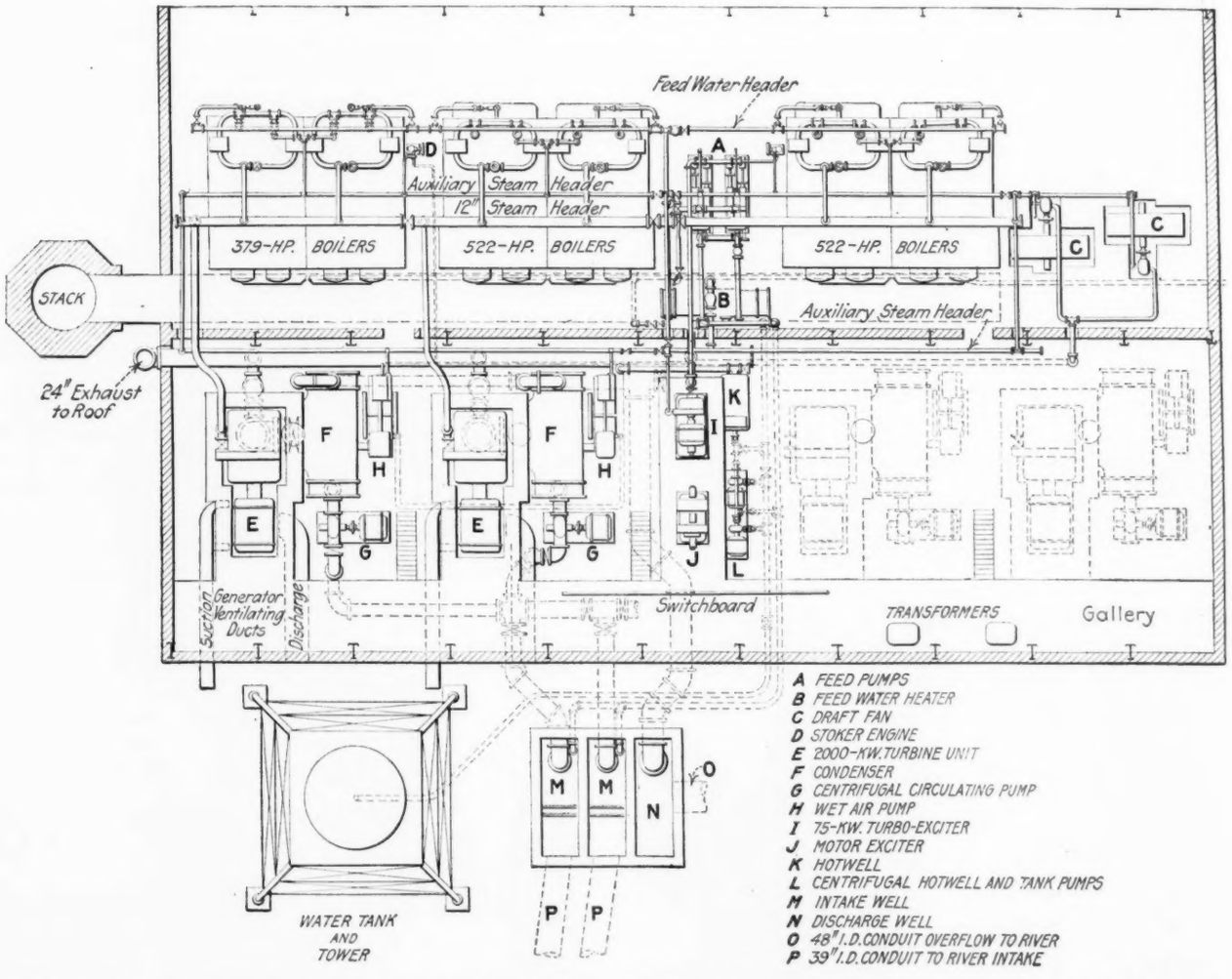


FIG. 4. PLAN OF THE TURBINE AND BOILER ROOMS, SHOWING GENERAL ARRANGEMENT OF THE APPARATUS

Ashes are loaded by hand into an ash car that also runs on the industrial track in front of the boilers. For some time to come they will be used for filling-in purposes about the yard.

A general view of the turbine room is shown in Fig. 6. The two new units are each of 2,500-kv.-a. capacity, 80 per cent. power factor. The turbines are two-stage and operate with 175 lb. of steam superheated 150 deg. The generators deliver energy at 2,300 volts, three-phase,

60-cycle, at 3,600 r.p.m. These units are on concrete foundations that are constructed to carry turbines of 4,000-kv.-a. capacity should it become desirable in the future to increase the output of the plant above its present contemplated capacity. By planning for future enlargement of the station in this manner, the larger equipment can be installed with the least delay and inconvenience to the plant operation.

The top of the turbine foundation is 10 ft. 9 in. above the basement floor, which is 2 ft. 6 in. below the boiler-

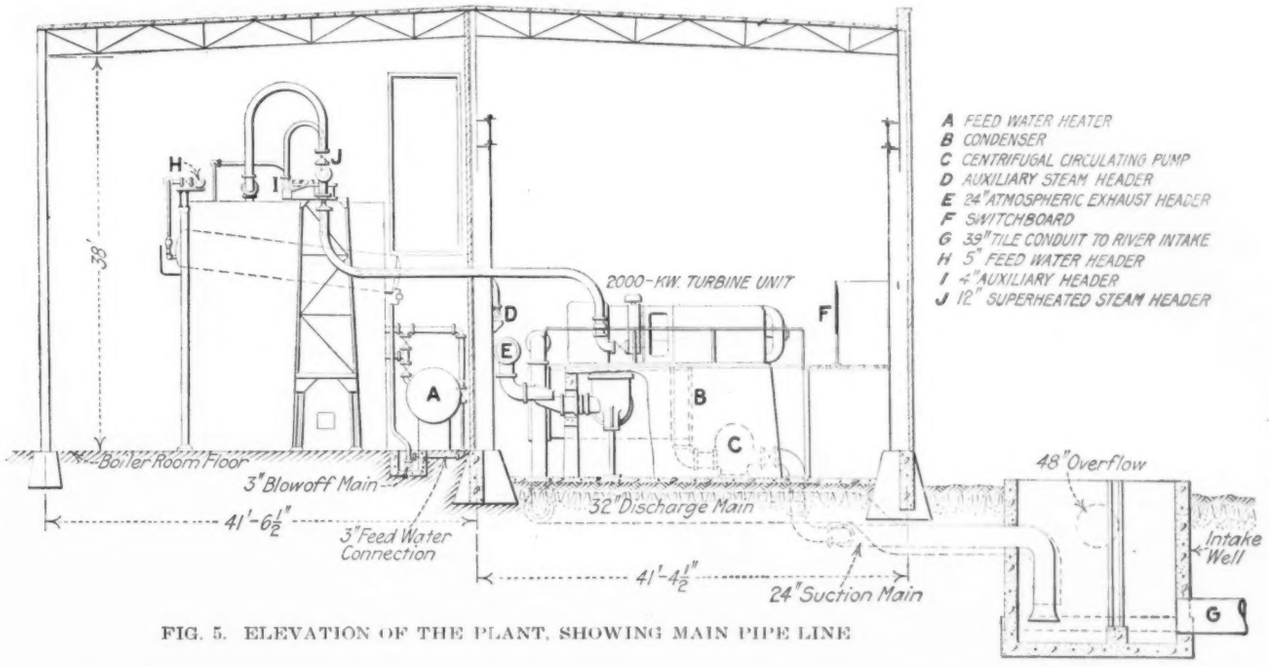


FIG. 5. ELEVATION OF THE PLANT, SHOWING MAIN PIPE LINE

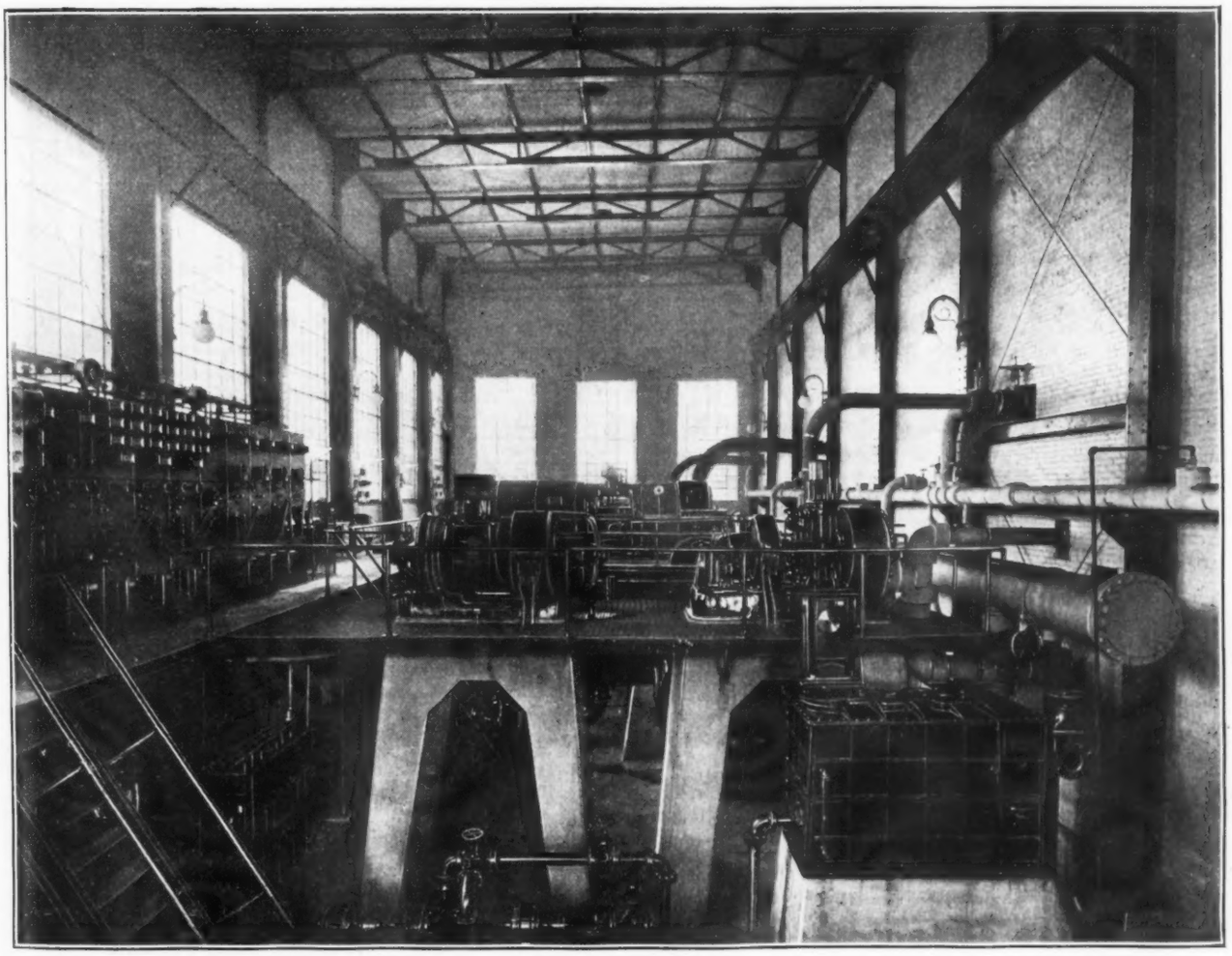


FIG. 6. GENERAL VIEW OF THE TURBINE ROOM, FOUNDATIONS AND BASEMENT

room floor level. The turbine room has a gallery 8 ft. 1 in. wide along the side farthest from the boiler room. This, with the platform surrounding the generator units and exciters, constitutes the flooring, thus leaving the condensing apparatus and other auxiliary units in the basement visible to the operator on the turbine floor.

A plant of this size, with such an arrangement has the advantage of being operated with fewer men than if the auxiliary apparatus were confined to a closed basement,

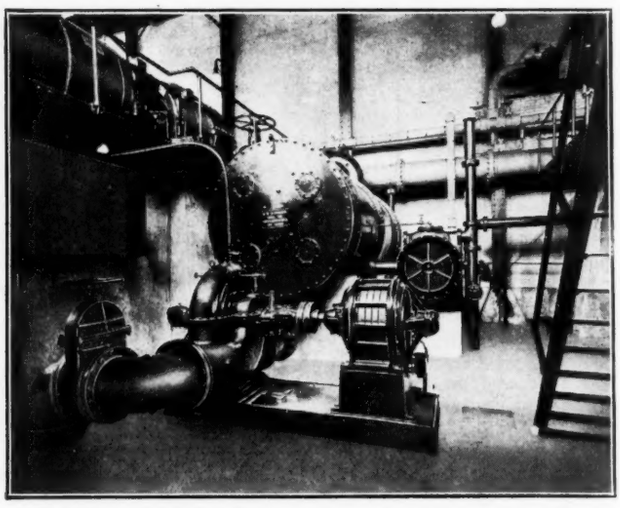


FIG. 7. MOTOR-DRIVEN CIRCULATING PUMP

in which case one or more men would have to be employed to care for the machinery.

A smaller turbine unit of 1,000-kw. capacity has been removed from the old station and installed at the right of the hotwell and tank pumps, as shown in Fig. 4 by the dotted lines. The fourth designated unit will not be placed at present.

Air for cooling each generator enters the casing through a 15-in. square galvanized-iron ventilating duct that extends to the outside of the building. The air is exhausted through a similar duct 27 in. square.

The main generators are excited from either of two exciter units, one turbine and one motor driven. The turbine is of 75-kw. capacity and is directly connected to a 75-kw. direct-current 125-volt generator at 3,600 r.p.m. The motor is of 115 hp. and drives a 75-kw. 125-volt generator. These units are on a concrete foundation level with the turbines. The turbine runs noncondensing, the exhaust steam being used in the feed-water heater.

Details of the Condensing Apparatus

Each of the two main turbines is connected to a surface condenser in the basement, resting on concrete piers. Circulating water is supplied to each by a 25-in. motor-driven centrifugal pump, Fig. 7. The motor is of 35 hp. and drives the pump at 600 r.p.m. It is controlled by a starting compensator attached to the motor frame. Each condenser contains 6,000 sq.ft. of cooling surface consisting of 1-in. tubes 12 ft. long and is designed to condense 20 lb. of steam per kilowatt, or 40,000 lb. of steam per hour. This gives 3 sq.ft. of condensing surface per kilowatt of turbine output.

Circulating water is taken from the Potomac River, which is dammed 1⅓ mi. below the plant, backing the water up for a distance of about three miles. The water intake is over a spring in the deepest part of the river, and as a result of the foresight in placing the intake where it is (the presence of the spring being known to Mr. Eyler from his boyhood swimming days), the water goes to the condenser at 58 deg. in the summer, although the temperature of the water in the river is 82 deg.—a difference of 24 deg.

Two 39-in. conduits run from the intake to two intake wells, each 15 ft. 3 in. long, 5 ft. wide and 15 ft. 6 in. deep (Fig. 4). The circulating pumps take water from either through a 24-in. pipe that runs to a 24-in. header in the basement. The permanent racks at the mouth of the intake conduits are supplemented by removable screens in the intake wells. From the header a 16-in. pipe runs to each circulating pump. The header is designed for a continuation toward the right, Fig. 4, for connecting to future circulating units.

The discharge water from each condenser is through a 16-in. pipe. At the second condenser the discharge pipe enlarges to 32 in. to handle the volume of water from the two, and discharges into a well that is 15 ft. 3 in. long, 5 ft. wide and 13 ft. deep. This well discharges from the side through a 48-in. overflow to the river below the intake.

A 6-in. connection from the intake wells runs to the hotwell and to the boiler-feed pumps. The well will handle 20,000 gal. of water per minute at maximum capacity, with but 15 deg. increase in temperature between the intake and discharge water.

The 12-in. main header, which is blanked at both ends for future extension, is of steel, with welded nozzles throughout. All main valves are of steel body, with monel-metal disk and seat. The main header is pro-

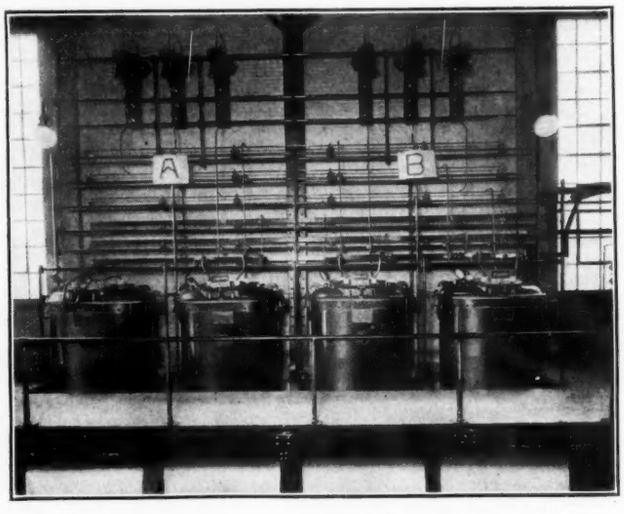


FIG. 8. SINGLE-PHASE 60-CYCLE TRANSFORMERS

tected by six nonreturn valves and the 4-in. saturated steam header by six more. An examination of Fig. 4 shows that the piping is on the unit system. Each two boilers and one turbine form a separate and complete unit. The 12-in. header is carried above the boilers and is sectionalized by three 12-in. gate valves. Steam from each superheater goes to the main header through a 6-in. pipe. An 8-in. branch drops from the main header and connects with each turbine.

There is also a 4-in. saturated auxiliary header in the boiler room and another running along the partition wall in the turbine room. The one above the boilers connects with each pair by a 2½-in. pipe valved so as to take steam from either boiler or both. The boiler-room header supplies steam to the stoker engines through 1½-in. pipes and to the fan engines through 3-in. pipes. There is also a connection from the 12-in. superheated-steam header at each end to the 4-in. header, which is piped with a 4-in. connection at the ends to the 4-in. header in the turbine room. This last-mentioned header supplies steam to the air pumps and to the turbo-exciter unit, which is also piped to the auxiliary header in the boiler room. With this arrangement of steam piping the necessity of a complete shutdown of the plant is practically avoided. The headers are supported at the ends and at the center by self-supporting structural steelwork.

Each main turbine has a 16-in. exhaust, connecting with a 24-in. main atmospheric-exhaust pipe. The auxiliaries all exhaust to a main exhaust line that varies in size from 4 in. at one end to 6 in. at the other. The connection to the heater is 8 in.

PRINCIPAL EQUIPMENT OF THE POWER PLANT OF THE CUMBERLAND EDISON ELECTRIC ILLUMINATING CO.

No.	Equipment	Kind	Size	Use	Operating Conditions	Maker
6	Boilers	Water-tube	522-hp	Steam generators	Forced draft, 175-lb. steam, 150-deg. superheat.	Heine Safety Boiler Co.
6	Stokers	Five-retort		Boiler furnaces	Engine-driven	American Engineering Co.
2	Engines	Vertical	5½x6-in.	Driving stokers	Variable-speed, 175-lb. steam	American Blower Co.
2	Fans	Sirocco		Forced draft	Variable-speed, 175-lb. steam	American Blower Co.
2	Engines	Vertical	7x7-in.	Driving forced-draft fans	Variable-speed, engine-driven	American Blower Co.
2	Pumps	Pot-valve, duplex	12&8x12-in.	Boiler-feed	Variable-speed	C. H. Wheeler Mfg. Co.
1	Heater	Closed		Heating feed water	Uses auxiliary exhaust steam	C. H. Wheeler Mfg. Co.
1	Meter	V-notch	100,000 lb. per hr.	Automatic metering condensate from turbines		Harrison Safety Boiler Works
1	Meter	Venturi		Metering feed water		Builders Iron Foundry
2	Pumps	Centrifugal	3-in.	Makeup and tank water	Motor-driven, 1,800 r.p.m.	C. H. Wheeler Mfg. Co.
2	Motors	Induction	7-hp.	Driving 3-in. centrifugal pumps	1,800 r.p.m., 220 volts	General Electric Co.
1	Tank	Wooden, round	30,000-gal. cap.	Priming pumps, fire protection	Filled by hotwell pumps	W. E. Caldwell Co.
1	Tower	Structural-steel		Supports house tank	For pump priming and fire service	W. E. Caldwell Co.
1	Chimney	Round brick	225-ft. high, 11-ft. int. dia.	Furnace gases	Forced draft	M. W. Kellogg Co.
1	Conveyor	Traveling		Coal to stoker hoppers	Motor-driven	Jeffrey Manufacturing Co.
2	Turbines	Two-stage	2,500-kv.-a.	Main generators	175-lb. steam, 3,600 r.p.m., three-phase, 60-cycle	General Electric Co.
1	Turbine	Two-stage	1,000-kw.	Main generator	175-lb. steam, three-phase, 60-cycle	General Electric Co.
1	Turbine	Single-stage	75-kw.	Driving exciter generator	175-lb. steam, 150-deg. superheat, 3,600 r.p.m.	General Electric Co.
1	Generator	Direct-current	75-kw.	Exciter unit	3,600 r.p.m., 125 volts	General Electric Co.
1	Motor	Synchronous	115-hp.	Driving exciter generator	1,200 r.p.m., three-phase, 60-cycle	General Electric Co.
1	Generator	Direct-current	75-kw.	Exciter unit	1,200 r.p.m., 125 volts	General Electric Co.
2	Condensers	Surface	6,000 sq.ft. of cooling surface	With main turbines	40,000 lb. steam per hr.	C. H. Wheeler Mfg. Co.
2	Pumps	Centrifugal	25-in.	With condensers	600 r.p.m., motor-driven	C. H. Wheeler Mfg. Co.
2	Motors	Induction	35-hp.	Driving centrifugal pumps	600 r.p.m., three-phase, 60-cycle	General Electric Co.
2	Pumps	Air	9x22x12-in.	With condensers	90 r.p.m. saturated steam	C. H. Wheeler Mfg. Co.
12	Valves	Nonreturn	4 and 12-in.	Between boilers and headers	Automatic	Lagonda Mfg. Co.
1	Switchboard	Slate	10-panel	Machine and circuit control	Hand-controlled	General Electric Co.
4	Transformers	Oil-cooled		Transforming current	2,300 to 11,000 volts, single-phase, 60-cycle	General Electric Co.

Details of the Electrical Apparatus

The 10-panel slate switchboard is on the gallery of the turbine room, handy for the operator. It is far enough from the wall to permit of installing the duplicate bus-bars at the back, where the oil switches are also placed. The switchboard is supported by a pipe framework and carries wattmeters, a watt-hour meter, voltage regulator and the necessary switches, etc.

Just beyond the switchboard there are the four single-phase 60-cycle transformers (Fig. 8), that receive the energy from the generator at 2,300 volts and raise it to 11,000, at which pressure it is sent to the substation, formerly the uptown plant in the city, over two lines, which come in from different directions to avoid trouble in case of a serious fire in the city.

A study of this station shows that it is well laid out, that special attention has been given to the pipe system and that provision has been made for an increase of the present contemplated output by putting in foundations that will accommodate much larger units than those now installed.

Operating Variable Temperature Refrigeration System

By Arthur L. Rice

Our plant being operated ten hours per day and with a somewhat different system from the standard, we have working temperatures varying from 45 deg. F. in the morning to 10 deg. in the afternoon. The plant is of the flooded type using double-tube brine cooler and condenser; the suction and discharge of the brine pipes are connected together, the brine going from the cooler to the storage rooms, back to the suction of the brine pump, then through the cooler, etc. A five-barrel tank is connected to the suction line, and elevated to take care of expansion and contraction of the brine; as the brine cooler is insulated on the outside instead of being submerged in the brine tank, the brine in the expansion tank is always at the temperature of the atmosphere.

With this system for intermediate service, one can get quicker action than is possible with the submerged cooler where there is a large quantity of brine to be cooled; then too, there is no radiation loss while the compressor is not running. We get nearly the same results as with the direct-expansion system, without having ammonia in the storage rooms to leak and cause a loss; all the brine that is cooled is that in the coils.

It will be noticed that we have a broad variation of temperatures to contend with, and this causes some trouble if the compressor is not operated in the proper manner to avoid hot piston rods and burned packing. As the heat taken from the storage rooms by the brine must be carried off by the condensing water, it is seen that the more water the condenser uses in a given time, the discharge temperature remaining constant, the more work is being done.

From experience with this system, we have found 84 deg. F. to be the most economical temperature for the

condenser discharge. We maintain an average condenser pressure of 175 lb. Of course, with the temperature of the gas at 115 deg. as it leaves the compressor, it requires a larger flow of water through the condenser. But to maintain a gas temperature of 115 deg. F. we carry a back pressure of from 15 to 45 lb. As the temperature of the brine drops the expansion valves must be closed.

With the gas temperature mentioned no jacket water is necessary. Also, the oil that gets into the compressor is taken out by the separator, as it never evaporates. We feed ten drops of Zero oil and powdered graphite per minute into the bottom of the stuffing-box for a 2-in. rod, or in that proportion, the top of the box being connected with the suction side of the compressor. The ammonia gas is never superheated, and I have found that the life of the ammonia is longer if it is not heated above 115 deg. F.

We pump our machines down to vacuum once a month to make sure there is no "dead" ammonia in the cooler coils, but at night and morning we start and stop on working pressures. By operating as stated there is little permanent gas to be purged from the system, the separator being blown out every Monday morning; hot piston pins and leaky packings are unknown. Our piston rod has not been packed for twenty months, and we never slack on the packing when starting compressor with 45-deg. F. brine; simply open the expansion valves a little. We take up on the packing on an average of once in thirty days and find this sufficient to avoid leakage and obtain a well-running rod.

Visits of Inspector Brown--X

By J. E. Terman

SYNOPSIS—Brown tests a new boiler for the value of the modulus of elasticity for steel plate, wins a bet from the shop superintendent on the result and later is informed by the Chief that he stood a good chance to lose.

One morning the Chief and Brown left the office to inspect some sawmill boilers about fifteen miles distant. On the way Brown opened the discussion by bringing up the subject of patches and the lengthening of the tubes under stress, previous talk upon which had set him thinking about the changes that took place in a boiler under pressure.

"I put one over on the boiler maker at O'Brien's this morning," announced Brown. "The superintendent is a bright, well-posted chap, who prides himself on keeping ahead of any of his men on all engineering questions. When I went to the shop they had a 72-in. boiler ready to test, and I decided to test the value of the modulus of elasticity for steel plate, and see if there was any difference from the values mentioned in connection with the lengthening of the tubes at the ice plant, by McGinnity's man. Before putting any pressure on the boiler I got a steel tape line and carefully measured the circumference, placing some small pieces of wood between the rivets at the longitudinal joint, to keep the tape line from sliding down between the rivet heads.

"While I was getting things ready the superintendent came by and wanted to know what I was doing. I told him that I was getting ready to test the modulus of elasticity of the shell.

"'What's that?' said he.

"I told him that I was getting ready to find out how much the shell stretched in circumference when pressure was put on the boiler.

"He just laughed at me and said that I must be nutty, and asked if I did not have sense enough to know that the boiler was made of steel plate and that when it got ready to stretch it was time for everybody to take to the tall timber. I saw that he was not up on the behavior of steel under stress and that he evidently thought that it was practically rigid under an ordinary working load. I told him that there was nothing on earth that was absolutely rigid and impenetrable, unless it was the skull of the average boiler maker, and asked him if he had never heard of boilers breathing.

"He retorted that boilers had more right to breathe than some of the rattle-brained inspectors that were scattered over the country. To make the matter interesting, I offered to bet the superintendent a dollar that the circumference of the boiler would stretch about an eighth of an inch when I put on the test pressure of 225 lb. He took me up after we compromised matters, the superintendent betting that the tape line would not show a movement over $\frac{1}{16}$ in., and I bet that the movement would be $\frac{3}{32}$ in. or more, and we placed the stakes in the hands of the foreman.

"Well, we put the pressure on and carefully measured the circumference, and while it was not ⅛ in. it was fully $\frac{3}{32}$ in. larger, and I collected the money. The best part about it was that all the men in the shop knew that I had put one over on the superintendent.

"I came within an ace of losing that bet, and it has set me to thinking whether that value of 29,000,000 lb. per sq. in. is the proper one for steel plate such as is used in boilers. I know that I was not able to measure very accurately with a common steel tape line, but the length of plate I was considering was long, and I figured that I could measure the stretch indicated by the tape line to within less than $\frac{1}{64}$ in., for I used a steel scale to measure the increase, instead of a tape. My measurement was certainly off more than $\frac{1}{64}$ in. from what it should have been if 29,000,000 lb. per sq.in. is the correct value for the modulus of elasticity of the plate."

"Show me how you arrived at the ⅛ in. that you expected the plate to stretch," said the Chief.

"Well," said Brown, "the boiler was 72 in. in diameter and made of ½-in. plate and was built for 150 lb. working pressure, so that in putting on a 50-per cent. excess, the test pressure would be 225 lb. I figured that the stretch in circumference would be $\frac{1}{29{,}000{,}000}$ times the circumference, times the stress per square inch in the plate, and since the boiler was ½ in. thick, the stress per square

inch of section would be, the diameter, times the pressure, or 72 × 225 = 16,200 lb. The circumference in inches, was 72 × 3.14, or 226.08 in., therefore the stretch would be 16,200 × 226 ÷ 29,000,000 = 0.126 in."

"Well, your calculations are all right, Brown, but you have not taken into account one important feature that was not connected with the problem that we had on the stretch in the boiler tubes, and that is, that in the case of the boiler shell, you are dealing with material that is stressed in two directions. When you stress a piece of metal in one direction it lengthens in the direction of the applied stress and it also tends to contract in the direction at right angles to the line of applied stress, so that if you were measuring the stretch of a piece of metal stressed an equal amount in two directions at right angles to each other, you would find that there was an increase in the length both ways, due to the applied stresses, but the stretch would not be as much as it would with the two forces acting at different times. In the case of a cylinder, like the drum of a water-tube boiler, the stresses lengthways are about one-half of the amount that they are in a circumferential direction, and you would find a perceptible diminution in the stretch that would be expected in a direction lengthways the shell, also some decrease in the circumferential stretch.

"In the case of the horizontal return-tubular boiler you were measuring, the difference would be slight and I am surprised that you notice it so much, for the tubes reduce the endways stress, so that apparently it should have no effect on the girthwise measurements. There is one thing to remember, you cannot hope to measure accurately enough with a steel tape, even with the length of material considered, to dispute the established value for the modulus of elasticity of steel, of about 29,000,000 or 30,000,000 lb. per sq.in. You might get into an argument with Jones as to the correct diameter of a boiler and prove to him that you could measure the average diameter to within $\frac{1}{16}$ in. by measuring the circumference, but you are a little out of the boiler inspector's province when you attempt to determine the modulus of elasticity. However," continued the Chief, "your attempt has done you no harm, and you are in that dollar."

At this stage in the conversation the train was announced, and Brown and the Chief were soon on their way to the sawmill.

A Surveying Instrument with some of the qualities ascribed to divining rods is in considerable demand, according to a prominent manufacturer of surveying instruments. He says he receives several letters such as the following in the course of a year: "Kindly send your catalog with prices of instruments that locate gold and silver in the earth."

Oil for Air-Compressor Cylinders should have a flashpoint of 550 to 600 deg. F., according to the air pressure and rapidity of compression; for steam cylinders operated with superheated steam upward of 600 deg., according to the amount of the superheat. Saturated steam will not disintegrate oil of 550-deg. flashpoint. For internal-combustion engine cylinders oil of as low flashpoint as will do the work should be used (about 450 deg.), as the heavier oils are apt to leave a sooty residue.

"Imperial" Vacuum Pump

For condensing and other service where a high degree of vacuum is desired, the Ingersoll-Rand Co., 11 Broadway, New York City, has recently introduced a line of steam- and power-driven duplex-type, "Imperial" vacuum pumps. A sectional view through a steam-driven unit is shown in Fig. 1.

The vacuum cylinder has Corliss-type intake valves so placed in the cylinder head that the clearance is exceptionally low, and the air trapped in the clearance spaces at the discharge pressure will not reach such a volume, upon being expanded to the intake pressure, as to greatly limit the pressure reduction that may be obtained. The action of the valve is positive and quick, and being independent of the cylinder and intake pressures, the pressures within and without the cylinder are as nearly equal as possible.

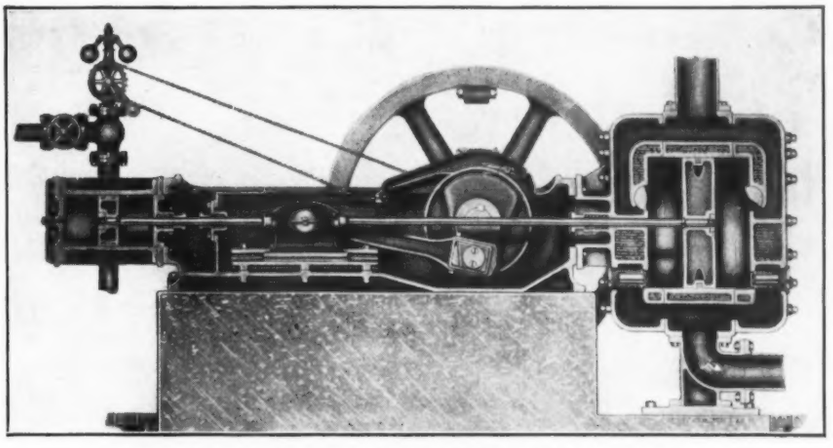


FIG. 1. SECTION THROUGH "IMPERIAL" VACUUM PUMP

The intake ports are large and direct. This, together with the water-jacketing of the valve, tends to cool the intake gases.

The discharge valves, which are of the direct-lift poppet type, are in the bottom of the cylinder heads so that entrained moisture or water is immediately discharged, a feature that makes for safety in handling moist or even saturated vapor. Clearance at the point of discharge has been reduced by making the valve partly fill the port in the cylinder head. The discharge passages are also water-jacketed. Tie-bolts pass from head to head and hold the cylinder and the heads tightly together. Lubrication is

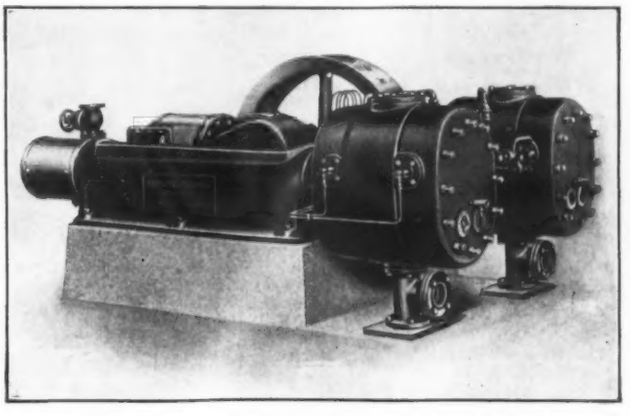


FIG. 2. DUPLEX "IMPERIAL" VACUUM PUMP

by the bath system, providing automatic flood lubrication, yet retaining, by the removal of covers from the casing, all the accessibility of the open type of machine.

The duplex construction, Fig. 2, makes it possible, should the requirement fall temporarily below that for which the equipment was originally installed, to remove one connecting-rod and discontinue the operation of one half of the machine, while the other half operates at its rated speed and efficiency, displacing, however, one-half the vapor that the entire machine is capable of handling.

These machines are built in capacities from 798 to 7,048 cu.ft. per min., both for atmospheric and low-pressure (5 lb.) discharge.

How Much CO_2 to Expect

By Victor J. Azbe*

SYNOPSIS—Deals chiefly with the maximum percentages of CO_2 that may be obtained with various kinds of fuel and explains why these amounts are maximum.

While flue-gas analysis is a comparatively simple matter, there are points about it that are not generally enough known, and because of this there are many misconceptions as to the CO_2 obtainable and the corresponding fuel loss.

Most of the tables of CO_2 percentages and corresponding losses of fuel in use are computed upon the basis that the fuel burned is pure carbon and that the maximum CO_2 obtainable with the theoretical air requirements is 20.9 per cent., say 21 per cent. The fuels in use are usually far from being pure carbon, and because of their composition such a table becomes of little value for the accurate comparison of results.

The maximum theoretical CO_2 with all fuels excepting pure carbon is lower than 20.9 per cent., and consequently the maximum economical and practical percentage will be lower. Take plants where oil fuel is burned. With some light oils only 14 per cent. CO_2 will be obtained under the most excellent conditions, and this in spite of the fact that oil requires only from 10 to 20 per cent. of excess air. Under some conditions, with the same oil, it would not be advisable to go so high.

The foregoing is generally the reason that some power plants operating with high CO_2 are losing considerable fuel because of incomplete combustion. It does pay to reduce the air supply, but it does not pay to reduce it so much that incomplete combustion results.

All fuels are composed of the following elements in variable proportions: Carbon (C), hydrogen (H), sulphur (S), oxygen (O), nitrogen (N); with certain amounts of ash and moisture.

The most important element in the fuel is carbon (C) which combines with the oxygen (O) of the air and forms CO_2 gas. $C + O_2 = CO_2$. The amount of carbon dioxide given off necessarily depends upon the amount of carbon present in the fuel burned.

Hydrogen (H) is the second important combustible of a fuel and in combustion combines with oxygen to form water. $H_2 + O = H_2O$. Hydrogen is the element that is the indirect cause of reduction of CO_2 in the flue gases, due to the nitrogen brought into the furnace with the oxygen required for its combustion.

The third combustible, sulphur (S), combines with oxygen to form sulphur dioxide (SO_2). $S + O_2 = SO_2$. Its presence in considerable quantities in the fuel is detrimental to the latter's quality, but will cause CO_2 percentages on analysis to appear higher, as SO_2 is absorbed together with CO_2 when brought in contact with a caustic-potash solution.

The chemical formulas indicating the absorption are $CO_2 + {}_2K(HO) = K_2(CO_3) + H_2O$ for carbon dioxide, and

$SO_2 + {}_2K(HO) = K_2(SO_3) + H_2O$ for sulphur dioxide.

The fourth element entering into the composition of fuel is oxygen, the amount of which is greatest in wood and least in anthracite. Its presence is as harmful as an equal amount of additional ash in coal, and the more of it a fuel contains the less will be its value. Some hydrogen is made unobtainable for combustion because of the oxygen, as the latter is combined with the former to the extent of one-eighth of oxygen by weight. Owing to this decrease of available hydrogen the percentage of CO_2 will be increased more or less.

The fifth element, nitrogen (N), plays no important part except that it dilutes the gases and thus lowers the CO_2, but its volume compared with the volume of oxygen and nitrogen brought into the furnace as air is so small that it has no important effect. After the fuel is burned with the air, the products of combustion will be carbon dioxide, water vapor, sulphur dioxide; and in addition to this, the nitrogen from the air that was used in combustion, and with excess air, additional nitrogen and free oxygen.

If a sample of gas from the uptake flue is drawn into the orsat and analyzed, the volume will be obtained less the hydrogen and its share of oxygen which combine to

TABLE 1. SHOWING AIR REQUIRED TO BURN BITUMINOUS COAL, AND THE CO_2 OBTAINED

Composition—Ultimate analysis, per cent.: H, 5.09; C, 62; N, 1.07; O, 13.86; S, 4.25; ash, 13.72. Proximate analysis, per cent.: Moisture, 6.28; volatile matter, 38.92; fixed carbon, 41.08; ash, 13.72. Volumes are in cubic feet at 32 deg. F.

Air Used (Lb.)	8.48		10.60		12.72		14.84		16.96		19.08	
Air Used (Per Cent.)	100		125		150		175		200		225	
	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.
Carbon dioxide (CO_2)	18.50	18.12	18.50	14.40	18.50	11.95	18.50	10.22	18.50	8.92	18.50	7.91
Nitrogen (N)	83.15	81.43	103.96	80.97	124.77	80.66	145.58	80.44	166.39	80.27	187.20	80.14
Oxygen (O)	.....	.....	5.49	4.27	10.98	7.09	16.47	9.09	21.96	10.59	27.45	11.75
Sulphur dioxide (SO_2)	0.47	0.45	0.47	0.36	0.47	0.30	0.47	0.25	0.47	0.22	0.47	0.20
Total	102.12	100.00	128.42	100.00	154.72	100.00	181.02	100.00	207.32	100.00	233.62	100.00

*Combustion engineer, Anheuser-Busch Brewing Association, St. Louis, Mo.

form water vapor, and which will condense to form water and thus reduce the volume so much that it cannot be measured with the ordinary burettes used.

The greater the percentage of available hydrogen in the fuel, the smaller will be the CO_2 percentage with the same amount of excess air. This means that economy with a fuel capable of giving a small volume of CO_2 compared with other gases entering in composition of the final product, will not be any less than with a high CO_2 fuel so long as the excess air used is not more.

With wood the maximum theoretical CO_2 will be 20 per cent., which is high because all woods are high in oxygen, which combined with the hydrogen content, will hardly leave any of the latter for combustion, and thus air is admitted for the burning of carbon only, with the consequent high CO_2.

The CO_2 obtained when burning bituminous coal is indicated by Table 1, where it can be seen that with 50 per cent. excess air, only 11.95 per cent. CO_2 will be obtained and not 14 per cent., as tables computed upon carbon as a base will give.

The maximum theoretical CO_2 with semibituminous coal will be even lower than the foregoing bituminous coal because of the lower oxygen content and higher percentage of available hydrogen.

Anthracites are low in hydrogen and consequently the CO_2 obtained will be high, as indicated by Table 2. As a rule the lower the available hydrogen the higher will be the CO_2.

Table 3 shows the amount of CO_2 obtained with oil fuel and which, by reason of the high hydrogen and low oxygen content is low. Generally with heavy oils, if properly atomized and burned, a higher CO_2 will be obtained, as heavy oils are higher in carbon and lower in hydrogen than light ones.

Flue-gas analysis is not complete until the amount of oxygen and carbon monoxide is determined. High CO_2 means small amounts of excess air, and herein lies the danger of supplying too little excess air to facilitate a complete mixture and consequently avoid the formation of CO. Combustion in oil and gas furnaces should be checked for CO.

CO_2 recorders should likewise be checked with a three-pipette gas-analysis instrument, and close watch should be given to the stack also, as smoke might be formed. The appearance at times of thick smoke from stacks indicates frequently that the hunt for extreme economy has been carried too far, with a consequent loss due to CO. Light smoke is a more sure indication of proper conditions than no smoke at all; but to be sure, the best way is to analyze the gas for carbon dioxide, excess oxygen and carbon monoxide, as the last is invisible, and the absence of smoke will not indicate the absence of CO—incomplete combustion. Solid fuels should be burned with about 7 per cent. excess oxygen, which corresponds to about 50 per cent. excess air with furnaces of ordinary construction. In specially constructed furnaces in which the travel of gases is slow and where they are thoroughly mixed before striking the heating surface, a lesser amount of excess oxygen can be used. A thorough mixture of the gases is important. With oil fuel, under good conditions no CO and no more than 2 to 3 per cent. of oxygen should be found in the flue gas.

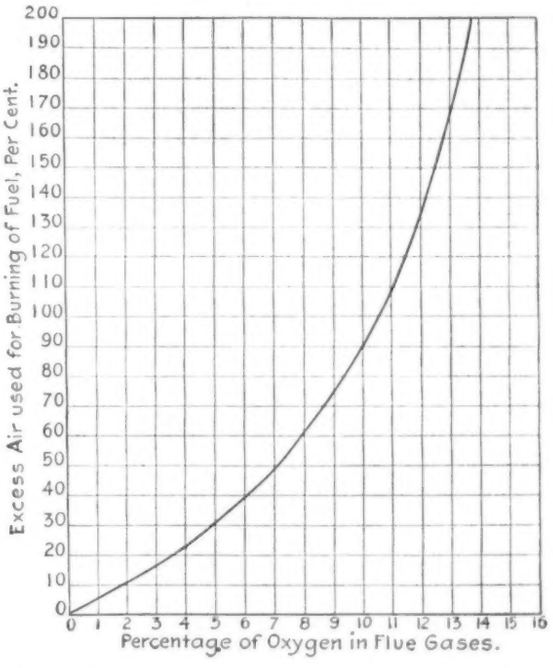
While the CO_2 percentage varies with different fuels for the same amount of excess air, the oxygen percentage remains constant with all.

The curve shows the relation between excess air and the oxygen percentage. Suppose we receive a certain

TABLE 2. SHOWING AIR REQUIRED TO BURN ANTHRACITE, AND THE CO_2 OBTAINED

Chemical Composition, per cent.: C, 78.6; H, 2.50; O, 1.7; N, 0.80; S, 40; ash, 14.8. Volumes are in cubic feet at 32 deg. F.

Air required	9.88 lb. / 100 per cent.		12.35 / 125		14.82 / 150		17.29 / 175		19.76 / 200		22.23 / 225	
	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.
Carbon dioxide (CO_2)	23.48	19.65	23.48	15.64	23.48	12.99	23.48	11.12	23.48	9.69	23.48	8.60
Nitrogen (N)	95.93	80.32	120.19	80.08	144.45	79.93	168.80	79.82	193.25	79.76	217.70	79.70
Oxygen (O)	.....	.....	6.38	4.25	12.76	7.06	19.14	9.04	25.52	10.53	31.90	11.68
Sulphur dioxide (SO_2)	0.044	0.03	0.044	0.03	0.044	0.02	0.044	0.02	0.044	0.02	0.044	0.02
Total	119.454	100.00	150.094	100.00	180.734	100.00	211.464	100.00	242.294	100.00	273.124	100.00



RELATION OF EXCESS AIR TO OXYGEN IN FLUE GASES

TABLE 3. SHOWING AIR REQUIRED TO BURN FUEL OIL, AND THE CO_2 OBTAINED

Chemical Composition, per cent.: C, 84.6; H, 10.90; O, 2.87; S, 1.63. Air required, theoretically 13.457 lb.; B.t.u., 18,958. Volumes are in cu.ft. at 32 deg. F.

Air used	13.457 lb. / 100 per cent.		14.802 / 110		16.147 / 120		17.492 / 130		18.837 / 140		20.182 / 150	
	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.	Volume	Per Cent.
Carbon dioxide (CO_2)	25.27	16.05	25.27	14.51	25.27	13.21	25.27	12.14	25.27	11.25	25.27	10.06
Nitrogen (N)	132.06	83.85	145.26	83.40	158.94	83.06	172.14	82.74	185.34	82.47	198.54	82.66
Oxygen (O)	.....	.....	3.48	2.00	6.98	3.65	10.46	5.04	13.94	6.21	17.42	7.21
Sulphur dioxide (SO_2)	0.17	0.10	0.17	0.09	0.17	0.08	0.17	0.08	0.17	0.07	0.17	0.07
Total	157.50	100.00	174.18	100.00	191.36	100.00	208.04	100.00	224.72	100.00	241.40	100.00

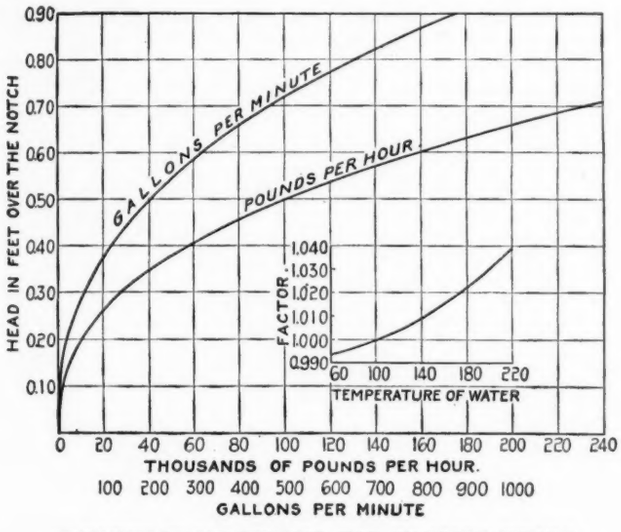
percentage of CO_2 from a fuel of unknown composition; we will not know what excess air we are using. But by analyzing the gas for oxygen also and by referring to the curve, the percentage of excess air will be obtained.

Flow Over V-Notch Weirs

By H. A. Cozzens, Jr.

A recently developed type of water meter that is rapidly finding favor in power-plant practice uses the V-notch principle. With these meters the station water rate may be readily obtained, and thereby the most economical method of operating the station is learned. It is therefore important that they should be commercially accurate and proved by comparison with the actual weight of the water or by other means. The use of the hook gage is popular, some manufacturers having installed them on their products, but where this has been neglected the tank may be drilled and tapped and a portable gage attached as needed.

The prime advantage of this mode of calibration is that the meter can be tested while operating under actual



V-NOTCH FLOW CURVES, FOR VARIOUS HEADS

station conditions and the average gage reading computed and checked against that found by the integrator or by planimetering the chart. The flow through the meter can be regulated and a series of readings taken for different flow rates. By this last method it is possible to plot a curve, as shown by the chart, showing the accuracy of the meter over the entire range, and where the meter is subjected to wide variations in flow this is most satisfactory.

The formula for the computation of water flowing over a V-weir may be found in most works on hydraulics and may be expressed as follows:

$$Q = \tfrac{8}{15}\, C \sqrt{2g}\, H^{\frac{5}{2}} \tan\frac{\theta}{2}$$

where

H = The height in ft. of the water over the notch;
Q = The quantity of water in cu.ft. per sec.;
θ = The angle formed by the sides of the notch;
C = A constant, taken as 0.592.

When the angle is 90 deg., the tangent of one-half the angle becomes unity and the formula reduces to

$$Q = 2.53\, H^{\frac{5}{2}} \qquad (1)$$

Many prefer to express this formula as

$$Q = 0.305\, H^{\frac{5}{2}} \qquad (2)$$

where

Q = The quantity of water in cu.ft. per min. instead of per sec.;
H = The height in inches instead of ft. of the water over the notch.

When the quantities are desired in pounds per hour, formula (1) must be multiplied by the product of 3,600 and the weight of one cubic foot of water at the temperature of the water passing through the meter. In the curves plotted the quantity of water at a temperature of 100 deg. F. is shown against the head over the notch in feet. When the temperature is other than 100 deg., the reading obtained from the first curve should be multiplied by the factor for temperature taken from the second curve.

Some German Power-Cost Estimates

Differences in American and European practice are so often placed upon the ground of the difference in the costs of the various factors on the two sides of the ocean that the following estimates of installation and operation costs, taken from a paper by L. Schulte in the *Zeitscrift des Vereines Deutscher Ingenieure*, will be read with interest. The article deals with the installation of a 1,250-kw. mixed-pressure turbine in a coal mining plant, and the author estimates the cost of:

A high-pressure steam turbine with generator for 1,250 kw., including freight, packing, erecting, condenser, cooling tower, piping, foundations, switchboard and engine house, 155,200 marks ($36,937.60), or $29.47 per kilowatt, not including boilers.

A mixed-pressure turbine including, besides the foregoing items, an exhaust steam accumulator of the gasholder type and exhaust-steam piping, 225,000 marks ($60,690), or $48.55 per kilowatt, with no boilers included.

With the high-pressure turbine three additional boilers of 100 sq.m. (1,076 sq.ft.) heating surface each would have to be installed, and he estimates the cost of these, including accessories, piping, foundations and setting, at 49,500 marks ($11,781), or about $36.50 per boiler horsepower. This would make the total expenditure required for the high-pressure turbine installation 204,700 marks ($48,718.60).

He estimates the cost of high-pressure steam at 1.60 marks per 1,000 kg., or 17.28c. per 1,000 lb.

The comparative costs of the two installations he estimates as follows:

COMPARATIVE COST OF HIGH-PRESSURE AND MIXED-PRESSURE TURBINE INSTALLATIONS

	High-Pressure Turbine		Mixed-Pressure Turbine	
	Marks	Dollars	Marks	Dollars
Interest and depreciation, 10 per cent.	20,470	4,871.86	25,500	6,069.00
Attendance, 16 hr. per day, 300 days.	1,920	456.96	1,920	456.96
Steam at 9 kg. (19.8 lb.) per kw.-hr.	69,120	14,736.96	21,880	5,207.44
Oil	490	116.62	500	119.00
Repairs	1,400	333.20	1,000	238.00
Attendance for 3 new boilers	2,800	666.40	.....	.....
Totals	96,200	21,182.00	50,800	12,090.40

The price of coal is taken at 7.50 marks per metric ton, which equals $1.83 per long ton or $1.62 per short ton. This is the cost price at the mine.

Decomposition of Ammonia and the Chances of Explosions

By Frank L. Fairbanks*

SYNOPSIS—Experiments in a large refrigerating plant carrying a charge sometimes as great as 100,000 lb. of ammonia fail to produce an explosion of ammonia gas and others by detonation. Mineral oil at high discharge temperatures becomes a hydrocarbon gas, highly inflammable and explosive when mixed with certain proportions of air. Segregated gases taken from the condenser and the absorber are inflammable and under some conditions explosive. When zinc or zinc alloys are in contact with the ammonia and the steam temperature in the absorber is high, decomposition of the ammonia occurs.

[The decomposition of ammonia in refrigeration plants and the possible and probable resulting explosive gases is a subject of growing importance as the refrigeration field becomes more extensive. The following letters from Mr. Fairbanks to the superintendent of the New York Board of Fire Underwriters Bureau of Surveys are by one who has had a wealth of experience in the theory, design and operation of refrigeration machinery, and who fortunately has the means to carry on experiments not possible or desirable in most plants or laboratories, the Quincy Market Co.'s system being the largest in the world and having both absorption and compression systems, besides a variety of auxiliary equipment. It is to be hoped that these letters and the abstract of Prof. R. Plank's paper on the same subject (highly technical, but acknowledged the foremost to date), which will soon appear in *Power,* will bring out the results of experiments and experience by others and the theoretical deductions of those competent to make them.—Editor.]

In reply to your letter inclosing "Special Report" on explosions and fires in refrigerating-machinery rooms I am pleased to say that several years ago I made an investigation of this subject to demonstrate by practical experiment, in so far as this was possible, the causes of so-called ammonia explosions in order to apply beforehand such remedies as would either eliminate them or reduce their possibility to a minimum.

The experiments were carried on at our Sargents Wharf plant, in which we have what is possibly the largest ammonia system in service, the working charge of which is sometimes as great as 100,000 lb. of ammonia, making it vitally important that every known danger of explosion be anticipated by proper safeguards.

Lubricating Oil Becomes a Hydro-Carbon Gas

We produced as near as could be obtained the supposed conditions that had caused explosions in other plants, and the result of our investigations, which seems satisfactory to us, was as follows:

Ammonia, NH_3 as such, is not inflammable or explosive in air.

There is, under certain conditions of operation, such as high temperature of discharge gases combined with moderate condenser pressures and high piston speeds, a slight decomposition of ammonia into its component elements, this being 1 atom of nitrogen and 3 atoms of hydrogen. The nitrogen is undoubtedly inert, but if the hydrogen has an opportunity to accumulate and segregate, it is inflammable and highly explosive when mixed with a favorable proportion of air and subjected to ignition, either by contact with open flame or by being subjected to a sufficiently high temperature.

We were unsuccessful in obtaining an explosion by detonation, such as might be expected to obtain in practical operation.

It is customary in practically all compressor operation to use in the compressor cylinders a mineral lubricating oil commonly known as ammonia cylinder oil. Practically all of these oils that have a cold test below zero have a flash test of from 275 to 350 deg. F.—American paraffin-base oils running toward the lower range and Russian olefine-base oils running toward the higher range.

Inasmuch as a temperature of 300 to 325 deg. F. is not an uncommon occurrence in practice (we have noted occasionally in our stations a discharge-gas temperature of 340 to 360 deg. on the mercury thermometers permanently connected for that purpose), the mineral oil used for lubrication, at this temperature becomes nothing more nor less than a hydrocarbon gas which, when subjected to ignition, is highly inflammable when mixed with certain proportions of air and highly explosive when mixed with certain other proportions.

Explosion of Gas from Condensers and Absorbers

Under ordinary conditions of operation and in ordinary temperatures the lubricating oil becomes finely atomized by churning, which obtains during the compression stroke and during the issuance of the gas and oil through restricted valve orifices, and this atomized oil is also inflammable or explosive when mixed with the proper proportions of air and ignited.

With reasonable care in operation there is never air enough in the working system to provide the aforesaid mixtures, but the conditions necessary for an explosion may be readily produced with either hydrogen gas of the decomposed ammonia, or the hydrocarbon gases from the oil escaping into the room in sufficient volume by reason of a mechanical rupture to the compressor or its piping and subjected to ignition; this ignition being possible by contact with an open flame, electric spark, arc lamps in service and rarely by contact with the hot filament, especially of the larger incandescent lamps when broken, and more rarely by the mechanical rupture itself. The higher the gas temperature at the time of release and mixture, the more readily is the explosion produced.

I have your favor of Oct. 28 in reply to my letter of the 23rd in relation to the inflammability, etc., of gases in refrigerating machinery.

*Chief engineer, Quincy Market Cold Storage and Warehouse Company, Boston, Mass.

In answer to your question, "Do I understand that you were successful in obtaining explosions of hydrogen, resulting from the decomposition of ammonia, when mixed with favorable proportions of air and ignited?" I am pleased to say that we were successful in getting both inflammation and explosion from a segregated gas taken from the condensers of our compression refrigerating machines, and the same results were obtained with a sample taken from the absorber of one of our absorption machines.

That there may be no misunderstanding, I wish to explain that this gas, when drawn from the condenser or absorber, ignited and burned readily in the air as it issued. A small sample, when allowed to stand for a short period so as to allow the lighter gas to come to the top and to be drawn off, was found to be hydrogen, which burned in the air as it issued, and when mixed with certain proportions of air and ignited was explosive, and when mixed with certain proportions of oxygen was very much more explosive.

As you are probably aware, practically all gases that are inflammable in air or oxygen are also explosive when a favorable mixture is obtained, the only difference between inflammation and explosion being in the time element of combustion; this time element being qualified by the intimacy and proportion of the mixture, and by the blanketing effect of any foreign or excess gas that may be in the mixture and that tends to slow down the chemical unition of the gases.

Explosions Unlikely in Closed System

We were unsuccessful in obtaining ignition at any of the temperatures of operation of the mixed gases as they existed inclosed in the system, and from our experiments we are inclined to believe that this cannot be easily accomplished, for the reason, we have assumed, that under operating conditions there is never air and consequently oxygen enough in the system to accomplish this result; the small amounts that obtain being so separated and blanketed by the noninflammable gas that if chemical unition takes place it is so slow and in such small quantity as to be negligible and not apparent from external observation.

The question of how much of this hydrogen gas is the result of ammonia decomposition and just how much of it is hydrocarbon liberated from the lubricating oil at high temperatures, especially the friction temperatures between the piston and the cylinder, is just now a much mooted point, our own opinion being strongly that a portion of it at least is the result of the decomposition of ammonia.

A committee was appointed by the American Society of Refrigerating Engineers, of which the writer is a member, over a year ago, to determine the sources of foreign gases in refrigerating systems, but owing to the lack of facilities for concerted action little was accomplished beyond proving that such gases were of quite common occurrence and interesting the Bureau of Standards in the subject to the extent that a considerable sum has been apportioned for the purpose of constructing a small plant by the aforesaid bureau at Washington, with a view to determine the facts under practical operating conditions.

In the July issue of the *Journal* of the American Society of Refrigerating Engineers there is an elaborate paper by Prof. R. Plank, of Danzig, Germany, which, while it is highly technical, is the most satisfying exposition of this subject that I know of, and it is especially so to us for the reason that it bears out theoretically the results that we have obtained by practical experiments, as well as furnishing hypotheses upon which we have been able to base satisfactorily the phenomena noted in operation.[1]

Hydrogen Gas Probably from Decomposed Ammonia

Referring to your report on the accident at the Manhattan Refrigerating Co., and in reply to your question, "Do you think it is probable that this is what occurred in connection with the explosion or fire incident to the liberation of gas from the plant using an absorption system, in which there was probably little or no lubricating oil?" I am pleased to say that from the description of the accident, it seems highly probable that the explosion was caused by the release of inflammable gases that were allowed to issue by the breaking of the pipe connection, and that had become segregated probably in the rectifier, and that were so intimately mixed with the air as to become explosive when ignited by embers in the forge.

I should expect that a portion at least of these gases was hydrogen resulting probably from ammonia decomposed in the generator.

It is a common thing for this segregation to take place, especially in the rectifier if at a high point, and if not, in the absorber. In fact it is so common that in our large absorption machines we can purge at any time desired gases that can be ignited as they issue into the air, and it goes without saying that if these same gases were intimately mixed with air in favorable proportions, ignition would result in an explosion.

I am quite satisfied that this decomposition does take place in the generator of the absorption machine, especially when steam of high temperature is used, and more especially so when zinc or zinc alloys are used in any part of the machine subjected to contact with the ammonia.

Zinc Deposit on Generator Coils

I have found galvanized piping used and have also found a considerable portion of zinc in what was supposed to be lead packings, gaskets, etc., and I have noticed on the generator coils a metallic zinc deposit which could have formed only from lead packings in the analyzer, which were almost completely eaten away, a remnant of this packing being found upon analysis to contain quite a percentage of zinc.

Under these conditions it is chemically possible to get a decomposition of ammonia, one of the results of which will be free hydrogen.

I would also suggest that it is easily possible for mineral oil, which may be used on the rods of the aqua pump, to work back through the packing into the other vessels of an absorption machine, with the possibility of developing a hydrocarbon gas, although I believe the possibility remote under ordinary operating conditions. We find continual evidence of the working back of this oil, as before stated, in our absorption machines, although of course the quantity is not large.

[1] [An abstract of this paper will soon appear in "Power."—Editor.]

In reply to your last question, "Do you feel, as the result of your experiments or experience, that the danger of igniting or exploding hydrogen, due to the decomposition of ammonia, is a fairly important hazard; or in other words, not one which is extremely remote?" I have to say that if you refer to internal explosion, that is, such explosion from this cause under operating conditions as would rupture a part of the machine, I think it is very remote, on account of the internal conditions as previously stated, and if you refer to external explosion due to the liberation of inflammable gases from either absorption or compression machines under conditions that may readily obtain during severe operation, the possibility is undoubtedly frequently present, although the probability of getting the proper mixture and ignition when such gases issue is quite remote, as demonstrated by the comparatively few accidents of this nature that have occurred in refrigerating plants. After the gases are formed and the proper mixture present there must be something to ignite the mixture to explode it.

However, severely abnormal conditions of operation can be deliberately produced that will provide the hydrogen, the oxygen and the temperature for the explosion.

There is a self-correcting feature nearly always present in the fact that practically all refrigerating plants using ammonia are subject to more or less constant leakage, through defective joints, valve stems, packings, etc., and this leakage usually relieves the system of the lighter and more mobile gases, especially if these leaks are about the condenser, which is generally the high point of the system, and as a rule the more careless the operation of the plant the more leakage; this condition thereby preventing automatically the accumulation and segregation of the inflammable gases, which constitutes the real source of danger.

To the careful operator the presence of foreign gases in the system is plainly indicated by the rise in both pressure and temperature, particularly the condenser pressure, which can be readily noticed on the gages which no plant should be without.

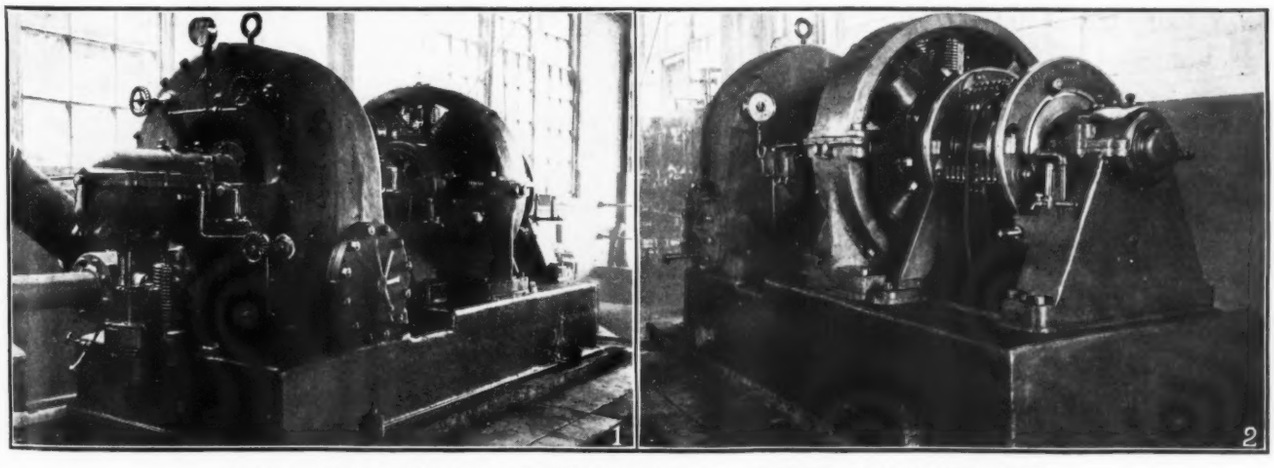
Wait Turbo-Generator on Elevator Load

SYNOPSIS—A 100-kw. single-stage turbine and direct-current generator specially designed to carry six electric elevators and numerous tungsten lamps simultaneously. The regulation is well within 2 per cent., and the economy can be varied to suit the requirements of the heating load.

A new era in isolated plants in office buildings is marked by a turbine installation in the Lumber Exchange Building, Chicago. This plant was described in the June 8, 1915, issue of *Power*, and brief reference was made to the turbine with which this article deals. The aim of the designers was to attain the maximum economy of operation for both summer and winter conditions. With this end in view they sought the most economical type of engine to carry the summer load. Engines of this character are so economical that they do not give sufficient exhaust steam for heating during cold weather.

The owners of this building operate a number of other office buildings, and careful experiments in these plants have proved that it requires a considerably greater percentage of coal to heat the buildings when operating on live steam through a reducing valve than when the heating is done with exhaust steam. They consequently desired a unit which could intentionally be made uneconomical, so that it would furnish enough exhaust steam to do the heating at night and on Sundays, and one that could be operated alone or in parallel with the engines, according to the amount of exhaust steam required.

To fulfill this service a turbine unit was selected, on account of the small maintenance and attendance requirements and also because of the small space occupied. The turbine set offers the advantage that its economy can be readily varied, so that if it is running at too economical a rate to supply the heating demands the nozzles and other details can be adjusted to give more steam for this heating service.



FIGS. 1 AND 2. THE WAIT TURBO-GENERATOR VIEWED FROM BOTH ENDS

Although the turbine was not intended to be economical, it will be seen from the tests that it compares quite favorably with the average engine. It also would be well to point out that if the turbine were intended for service where the economy was the chief factor, it would have been designed with this end in view and a higher efficiency obtained. As a matter of fact, it has been found in operating the building on the lighter loads that there is no great difference in the economy of the turbine and that of the engines. As the load decreases the turbine nozzles may be shut off so that the economy is maintained at the smaller loads.

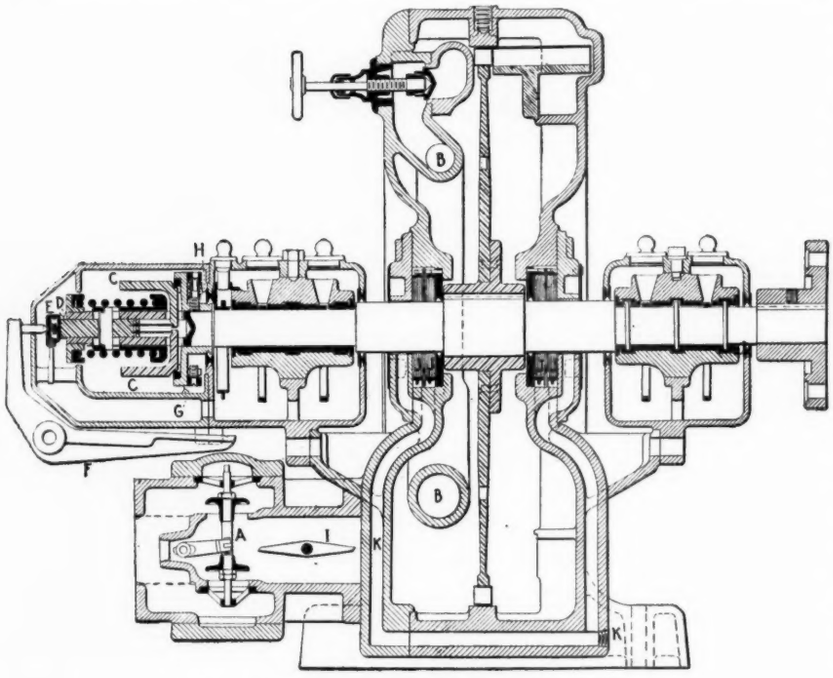


FIG. 3. SECTION OF THE WAIT TURBINE

In attempting to find a unit that would fulfill the foregoing conditions, the owners were at first unable to obtain a direct-driven turbine set that would carry a combined lighting and elevator load and meet the regulation requirements. It was therefore necessary to build a special machine, with these requirements in view. This problem was undertaken by Henry H. Wait, who for many years has been a steam-turbine and generator designer. The nominal size of this unit is 100 kw. at 230 volts and 2,200 r.p.m. On account of the severity of the requirements both the turbine and generator are heavier than would be necessary to carry loads that did not fluctuate so violently.

Fig. 1 shows the turbine unit as set up for the acceptance tests, which were made at the shops before installation in the building. It will be noticed that the set is simply resting on skids on the floor, and under these conditions the vibration was so slight that a five-cent piece could be kept standing on the bearings. Fig. 2 shows the set from the dynamo end and Fig. 3 a section through the turbine, which is of the single-pressure double-velocity-stage type, the steam path being shown in Fig. 4. The steam expands to approximately the exhaust pressure in the nozzle, and after passing through the blades the first time, continues by its residual velocity and is returned for a second impact on the blades. There are four nozzles (see Fig. 1) which may be controlled by hand to suit the load conditions and a fairly constant efficiency over a considerable range of load maintained.

After passing through the governing valves *A*, Fig. 3, steam enters the circular passage *B*, which distributes it to the four nozzles. The passage and nozzles are shown in Fig. 5. The latter are of a curved section to fit the periphery of the wheel, a cross-section through the steam jet being an approximate rectangle with rounded corners.

It will be noticed that the high-pressure steam goes from the governor-valve body into the passage *B*, so it is not in contact with the exterior of the turbine except where the shutoff valves are situated.

The governor is of the centrifugal type with fly weights *CC*, which act on the plunger *D* and carry the motion to the ball-bearing *E*. Thence the control is through the rockshaft *F*, mounted on ball bearings, and through a lever and ring to the valve *A*. All of the joints where the principal forces occur are knife-edges, so that the governor is extremely sensitive. In this machine, applying an oscillating force of one pound at the ball bearing makes a perceptible corresponding oscillation in the steam gage at the nozzle passage. The ball bearing is oiled by a pipe leading from the oil ring at the end of the main bearing, so that there are no oil cups on the machine and the whole set is self-lubricating and automatic. In operation the machine has run several days at a time without attention from attendants except to shut off the nozzle valves when the load decreases at night, leaving the men free for other duties.

FIG. 5. SHOWING THE PASSAGE AND NOZZLES

Besides the main governor, there is an auxiliary overspeed governor consisting of the ring *G*, which is slightly out of balance and overpowers the spring *H* in case of any emergency that would make the speed go higher than 15 per cent. above the normal. When this ring flies out it operates a trip releasing the butterfly valve *I*, which stops the turbine.

The stuffing-boxes consist of carbon rings *JJ* made in halves held together by garter springs. Any leakage of steam that gets by the carbons is carried away by the passages *K* and is led to a drain. In this particular installation there has not been enough leakage from the stuffing-boxes to necessitate connecting the drain. The carbons last several years before they need to be refitted.

The blades are made of "extruded" metal and are fastened to the wheel as shown in Fig. 6. There is an outer band, or shroud, surrounding the outer ends of the blades, and this is held in place by screws, as shown. These screws are notched into the band to keep them from turning.

The generator is of the four-pole type with interpoles, and the general construction can readily be seen in Fig. 2. The dynamo is larger than would normally be required for the rated load and special features are introduced to secure good regulation, essential with the elevator load.

The type of construction used in the armature is shown in Fig. 7, the principal feature of these high-speed armatures being the adequate retaining of the windings against the centrifugal force. In the core portion the bars are held in the slots by substantial wedges, and at the ends they are held by heavy solid retaining rings *AA*. The windings are first compressed against the cylindrical centers and the rings *AA* shrunk on. This makes a solid construction, and armatures built in this manner have run for years without showing any indications of shifting balance due to shrinkage of the insulation or looseness. The "magnetic fences" *CC*, formed by laminations that extend higher than the main body of the core, shield the retaining rings *AA* from magnetic leakage from the pole-pieces *B*, which would otherwise cause considerable eddy-current loss and heating. Commutator segments of like polarity are cross-connected by an equalizing winding behind the commutator, as at *D*.

The brush holders are mounted on rocker rings, which rest in saddles and are adjusted once for all when the machine is set up. They do not require movement during the operation, as the brushes run sparklessly even with violent fluctuations of load. The brushes are of graphite.

In an installation of this character the regulation of the set is the all-important feature, as it is necessary for economical operation to operate the lights and elevators from the same machine. As already indicated, good regulation is obtained in this set by making the dynamo unusually heavy and the high speed of the unit gives it considerable momentum to carry it through the jumps in the load caused by the elevators.

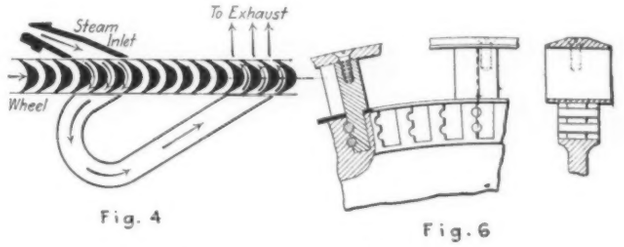


Fig. 4

Fig. 6

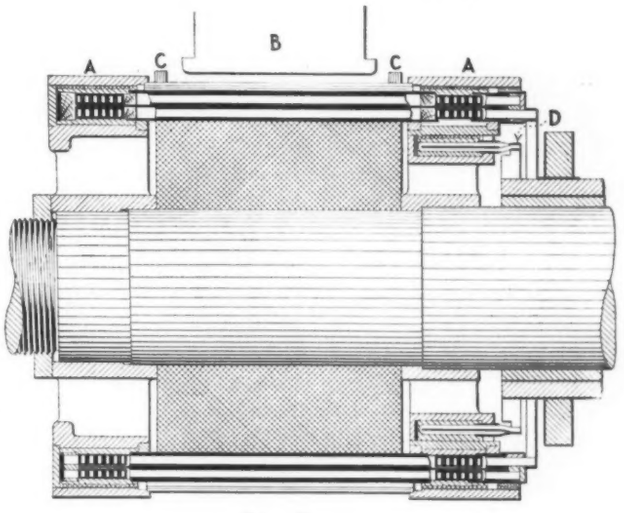


Fig. 7

FIG. 4. STEAM PASSAGE IN THE WAIT TURBINE
FIG. 6. DETAIL OF THE BLADE FASTENING
FIG. 7. SECTION OF THE ARMATURE

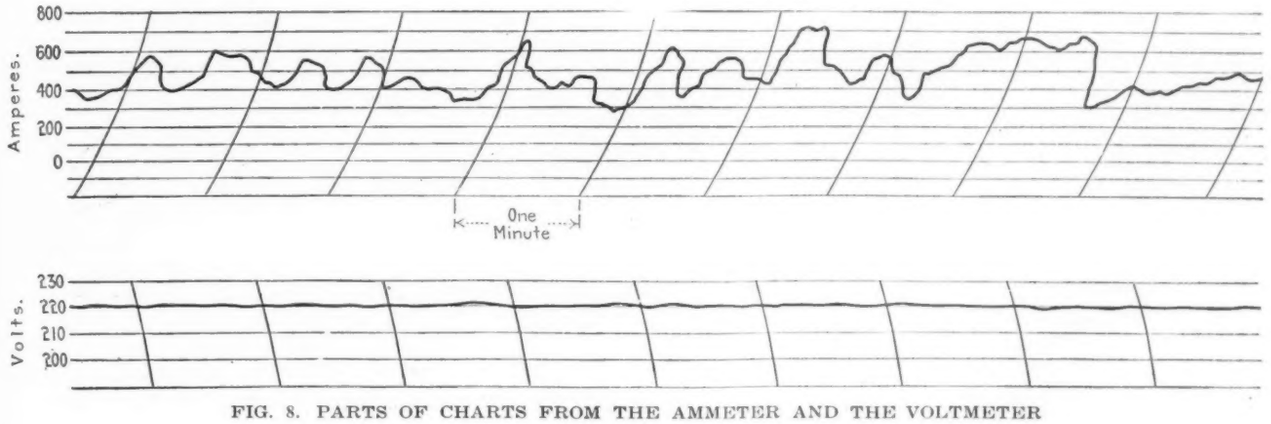


FIG. 8. PARTS OF CHARTS FROM THE AMMETER AND THE VOLTMETER

Results obtained at the plant are shown in the recording ammeter and voltmeter charts of Fig. 8. The upper curve shows the variation in current and the lower curve the corresponding variation in voltage. In this building at present the day load varies from 250 to 800 amp. In the section of the charts given, the minimum current as

observed on the regular switchboard ammeter was 280 amp. and the maximum, 730. The corresponding voltage variation on the switchboard voltmeter was from a minimum of 220 to a maximum of 225; that is, a maximum variation of 2½ volts from the average. The sudden drop in voltage when a single elevator is started is not much more than one volt.

TABLE 1. SUMMARY OF HEATING RUN

	Commutator	Armature			Fields		
	Hottest Part	Core	Winding	Air From Arm	Shunt	Series	Int. Pole
Rise after 2½-hr. run at miscellaneous loads up to 300 kw., deg. F	71	41	11	22	34	24	22
Rise after 5-hr. run at 100 kw. following above, deg. F	43	27	..	11	38	16	10.5
Rise after 2½-hr. run at 133-kw. following above, deg. F	41	..	28	12	39	..	10
Rise after 2½-hr. run at 150-kw. following above, deg. F	58	30	..	14	37	..	20
Rise after 1-hr. run at 300 kw. following above, deg. F	86	62	..	27	47	..	65

Elaborate acceptance tests were carried out at the shops at South Chicago by F. H. Getchell, of Holabird & Roche, and M. T. Kimman, chief engineer of the L. H. McCormick Estate, to determine the temperature rise in the generator, regulation and economy. The results of the heating tests on the generator are given in Table 1. It will be noticed that these temperatures are unusually low for high-speed machinery and are well within the requirements of the specifications, which call for extra low rises on account of the character of the room where the turbine was to be installed.

A summary of the steam-consumption tests is given in Table 2, which shows the pressures, temperatures, water rate and efficiency of the turbine. It will be noticed that the temperature of the steam delivered to the turbine corresponds to a superheat of approximately 40 deg. F.

TABLE 2. SUMMARY OF EFFICIENCY TEST

	100 Kw. on One Nozzle	Maximum Load on One Nozzle	Full Load on Two Nozzles
Volts	234.2	218.5	230.1
Amperes	423	572	1,006
Kilowatt	99	125	231.5
Revolutions per minute	2,200	2,175	2,100
Number of nozzles	1	1	2
Temperature at throttle, deg. F	404.5	400.3	.....
Pressure at throttle, lb. gage	140	139	133.9
Pressure at nozzle, lb	112.15	137.5	125.8
Back pressure, inches of mercury	0.23	0.25	0.55
Pounds per square inch	0.11	0.12	0.27
Steam Consumption, lb. per kw.hr: Actual	48.5	45.7	....
Approximate check estimate on assumption (incorrect) that steam is saturated at nozzle entrance	48.6	46.2	46.1
Efficiency of set, as compared with perfect heat engine, per cent	39.6	41.8	45.5

Such a plant would of course be objectionable if there were any undue noise or vibration; but the turbine cannot be heard outside of the engine room and vibration is so slight that it cannot be detected a few feet from the machine.

Effects of Varying Mixture and Ignition Timing

By Victor R. Gage*

SYNOPSIS—By comparing indicator diagrams the performance of a small gasoline engine was judged with different fuel mixtures and advancing and retarding of the spark.

The indicator diagrams shown in the chart, Fig. 2, were taken from a 6-hp. four-stroke-cycle horizontal stationary engine of 6-in. bore and 10-in. stroke. The hit-or-miss governor maintained the speed about constant at 300 r.p.m. except for the extremely small diagrams, when the engine had hardly enough power to overcome friction. The ignition was by jump spark, the timing lever moving over a suitably graduated scale. Load was applied with a prony brake and was so adjusted that there were about five explosions between the misses, the diagrams being taken on about the fourth explosion, so that they would truly represent the mixture of the setting of the needle valve.

Referring to the chart, the vertical columns show the number of turns that the needle valve was opened and the horizontal rows (except the bottom row) represent the percentage of the stroke which the piston had traveled at the time contact was made on the timer. The numbers within each space are the mean effective pressures in pounds per square inch, as shown by the diagram in that space. A circle around the mean effective pressure denotes that it is the maximum power for that setting of the needle valve, and the double circle shows the maximum for the entire set of cards, namely, 91 lb. per sq.in. In the cases where there was extreme retardation of the spark the reëxpansion of the gas above the com-

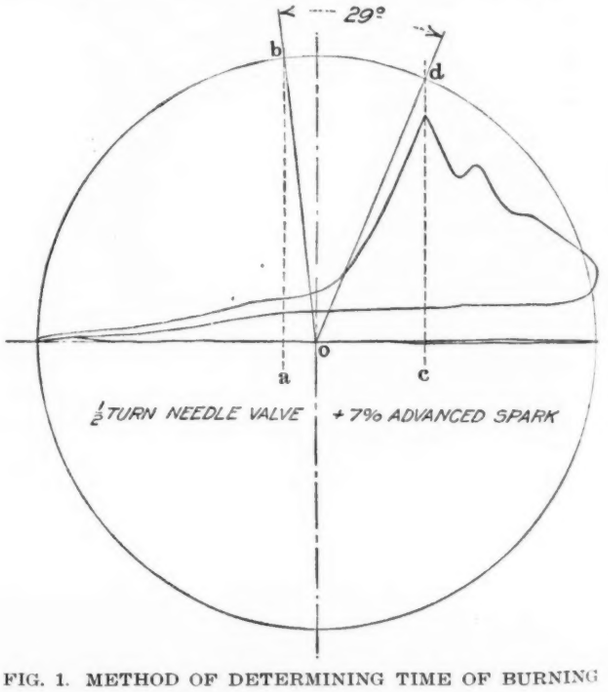


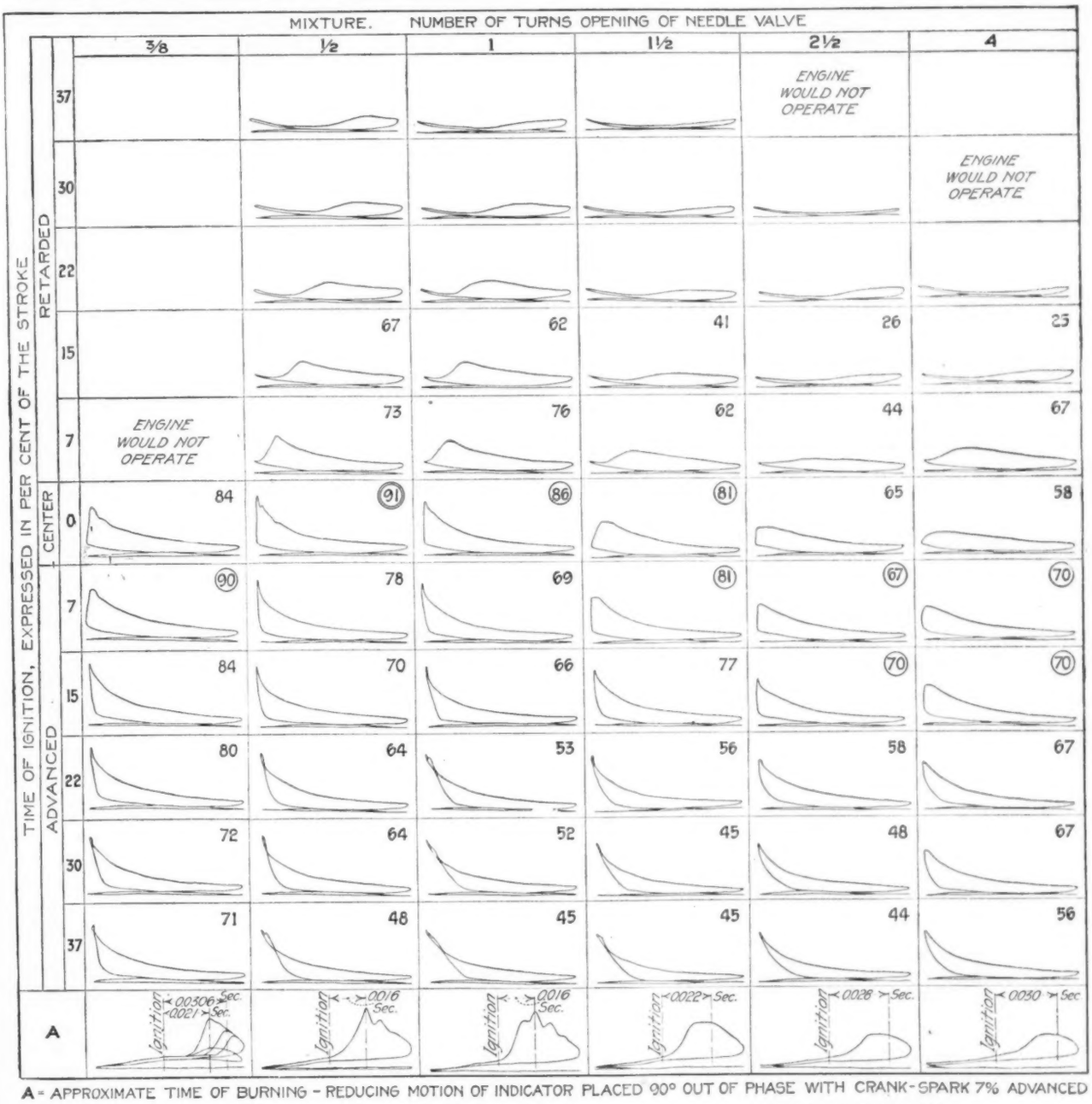
FIG. 1. METHOD OF DETERMINING TIME OF BURNING

*Assistant professor of experimental engineering, Sibley College, Cornell University.

pression line before ignition denotes the heating effect of the cylinder walls.

The diagrams in the bottom row were made by shifting the crank that drives the indicator drum so that it made an angle of about ninety degrees with the engine crank.

With 3/8 turn of the needle valve the operation of the engine was very troublesome, accompanied by backfiring; sometimes the mixture apparently did not ignite at all, at other times it seemed to just smolder, then it would burn well. The several diagrams in the square at the lower left-hand corner show the various ways the mixture burnt; it was very slow to ignite, but when started seemed to burn quickly at times, at other times slowly. With ½ turn of the needle valve the troubles were similar, although to a much less degree. Nearly one turn was required for satisfactory operation. With the needle valve opened more, the mixture again became slower-burning, but the characteristic form of the diagram was changed. This indicated that both the too lean and the too rich mixtures were slow-burning, and by following the encircled maximum mean effective pressures for various mixtures it is seen that it is necessary to advance the spark as the mixture is changed either way from what might be called a normal mixture. The diagrams with normal mixture and 37 per cent. advanced spark show the loop or negative work which is denoted to the ear by knocking.



A = APPROXIMATE TIME OF BURNING - REDUCING MOTION OF INDICATOR PLACED 90° OUT OF PHASE WITH CRANK-SPARK 7% ADVANCED

FIG. 2. SHOWING THE EFFECTS OF VARYING QUALITY AND TIMING OF IGNITION

The purpose of placing the indicator out of phase with the engine was to show the ignition line to better advantage. In all cases the left-hand dotted line is the point at which the spark occurred, the dotted line or lines to the right of this are the estimated points of complete burning, and the numbers represent the time required for complete burning. The method of computing the time required for burning is indicated in Fig. 1. A circle proportional to the crank circle is drawn on the

atmospheric line of the diagram as a diameter and lines *ab* and *cd*, representing the estimated points of ignition and complete burning, are extended to touch the circle at *b* and *d*, respectively. The angle *bod* is then found. At an engine speed of 300 r.p.m. one revolution will require 0.2 sec., and 29 deg. will require $\frac{29}{360} \times 0.2 = 0.0161$ sec.

Comparison of these diagrams, with the spark advanced 7 per cent., shows that the fastest-burning mixture was with ½ turn of the needle valve, although one turn is nearly as good. The operation of the engine was much more satisfactory with one turn. With the indicator timed in this manner, there is much more trouble from the effects of inertia, shown by the wavy lines on the fast-burning mixtures.

A study of these diagrams shows that not only maximum economy, but also maximum power, are obtained by adjusting the engine to run on as lean a mixture as possible, with the spark advanced only enough to overcome the lapse of time required for the mixture to burn, and to overcome the electrical lag.

Ball-Bearing Induction Motors

The predominant position of the induction motor is due to its simple and sturdy construction and its absence of sliding contacts, with consequent freedom from sparking and minimum wearing parts. The bearings are the only parts subject to wear, their life to a large extent determining the service obtainable from the motor. With this fact in mind, Fairbanks, Morse & Co. has placed on the market a motor equipped with self-aligning ball bearings.

As shown in Fig. 1, the bearings are mounted as a unit within a lubricant chamber filled with grease and sealed against grit and dust by close-fitting end caps, which also prevent the lubricant from leaking out. As the ball bearings occupy less space than other types, the projection of the housing is small, resulting in a reduction in the

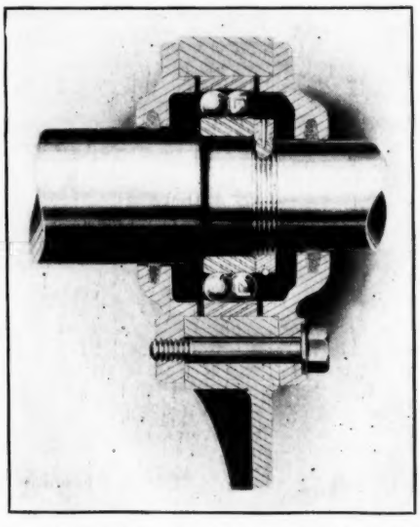


FIG. 1. SECTION THROUGH BEARING BRACKET

overall length of the shaft; therefore bringing the bearings closer together and giving greater stiffness to the shaft.

On the rotor the end rings are cast onto the rotor bars, so that the rotor winding is just solid metal without joints and is therefore free from the mechanical and electrical weakness of jointed structures. It should stand heavy overloads without injury.

Fig. 2 shows a part section through a vertical-shaft motor embodying the same improvements in construction. Self-aligning ball bearings are employed, and in all except the smaller sizes each motor is provided with a thrust

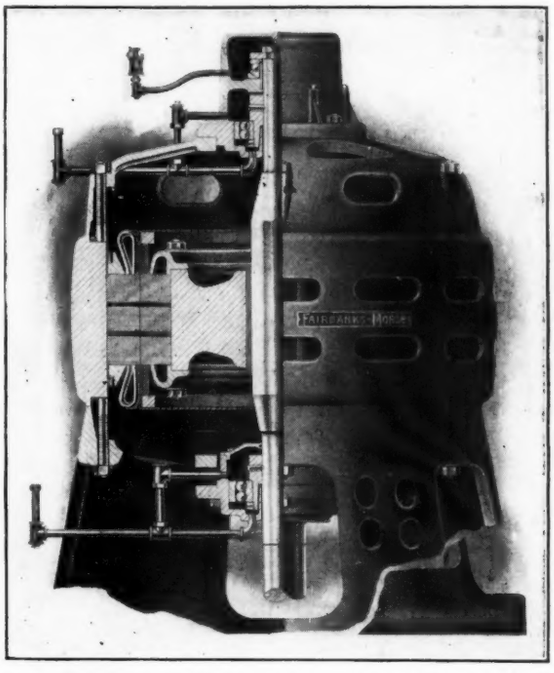


FIG. 2. VERTICAL MOTOR, SHOWING PART IN SECTION

bearing mounted in the upper bearing bracket on a self-aligning seat to take the weight of the rotor. In the smaller motors the two radial bearings are sufficient to carry the weight. Each bearing has an automatic oiling system. The motors may be furnished with a shaft extending either upward or downward.

Bolt Prevents a Shutdown

A large ice and cold-storage plant depended for its lights on a unit belt driven by a worn-out slide-valve engine. One night one of the studs that held the steam valve-stem gland pulled out of the valve chest and the engine was shut down, putting the place in darkness. The threads in the casting were gone and the hole extended through into the steam space. There was no tap to make new threads and no dies to make a new stud.

Prompt action was necessary. The valve-chest cover was taken off and a ½x4-in. bolt put through the hole from the inside. It was a fairly snug fit, and by using a lead washer and some asbestos wick packing little steam leaked by. The engine was run in this way for several days until a favorable opportunity came to put in a new stud.

No matter how small the plant or how reliable the lighting system, there should at all times be a lighted lantern within reach of the night engineer.

Tallow Oil, when derived from fresh tallow from properly fed animals, is a good lubricant, but lends itself readily to adulteration and may become rancid and acid. It forms the base of the best white soap, and if a large enough percentage of soap is added to the oil it becomes a grease.

Editorials

Condemning the Lap-Seam Boiler

Acting Chief Neal, of the Massachusetts District Police, is said, in consequence of the Weymouth explosion, to have suggested more stringent legislation with regard to the lap-seam boiler; perhaps its total disqualification. While we shall all be glad when they are gone, and while a calculation of the damage that they will probably occasion might justify heroic measures, any attempt to rule them out altogether would bring about a storm of protest that might wipe out all state boiler inspection for the time being and thus defeat reform by applying it too brashly.

It is not, however, necessary or advisable to go to this extreme. All lap joints are not dangerous, and there are many lap-jointed boilers that are not so likely to explode as some with butt-strapped joints. The essential is some method, short of cutting the boiler up, of determining which are the safe and which the unsafe joints. Such a method has been developed by the chief engineer of the Hartford Steam Boiler Inspection and Insurance Co. and was described in *Power* of July 14 of last year. Its use by the insurance company has disclosed many incipient fractures and saved some sound boilers that might otherwise have been condemned inferentially. A general test of lap-jointed boilers by this method would reveal the danger points and allow owners to go on using boilers that pass the test, in confidence of their present safety. There would be some interruption to service and some damage to settings in such an investigation, but owners should regard this as a welcome substitute for wholesale condemnation.

Massachusetts Cast-Steel Specifications

The proposed amendment to the Massachusetts Boiler Rules regarding cast steel for boiler and pressure vessels and the discussion at the recent semiannual hearing certainly lead one to conclude that the specifications offered are not commercially applicable.

These specifications are given on page 66 of the 1915 edition of the Rules, and state that the tensile strength shall be from fifty to sixty thousand pounds per square inch, with an elongation in two inches of twenty-three per cent.; the sulphur content is limited to not over five one-hundredths per cent.

Manufacturers claim that they cannot guarantee a cast steel to come within this limited range in tensile strength and at the same time conform to the chemical requirements of the specifications. This demands special heats and naturally narrows the source of available supply. All those participating in the discussion agreed that an upper limit of sixty-thousand pounds' tensile strength was undesirable.

It seems reasonable to amend these specifications if only for the sake of uniformity, making them the same as those of the American Society for Testing Materials, which are those specified in the A. S. M. E. Boiler Code. A maximum of five one-hundredths per cent. in sulphur, with a permissible excess of twenty per cent. of that amount, would facilitate manufacture and conduce to no harm. If the chemical requirements are conformed to it is likely that the tensile strength will take care of itself.

The board seemed interested and impressed with the discussion, and it is to be hoped that the specifications will be amended to conform to those generally approved and accepted.

Uniformity in Fusible Plugs

The function of the fusible boiler plug is to manifest an unsafe condition by the fusing of metal, thus liberating the pressure in the vessel and giving warning. Unquestionably, many designs of plugs may be made to meet these conditions, and if one wants to be finicky he can create a lot of disturbance by insisting that his selection, among many which will fulfill every requirement, should be accepted. If he gains his point in a particular locality, he is satisfied and does not give three whoops what is used elsewhere. But the general user and the manufacturer must needlessly suffer the costs and inconvenience of such inefficiency.

After a few needed and probable changes the Massachusetts fusible-plug specifications will be satisfactory. The specifications of the Supervising Inspectors of Steam Vessels are generally accepted as meeting every safety requirement. The Boiler Code specifications were accepted by every interested party, which is worthy evidence that they meet the demands on a fusible plug. But there are differences in these specifications.

If all would agree that the important qualification of a safety plug is safety, they might unite in accepting the one easiest to manufacture, making it available at minimum cost and applicable anywhere, therefore obtainable anywhere. Then when an outside or an inside or a tube plug is mentioned, it will mean the same thing to everyone.

Mastering a Situation

When reading the article describing the Cumberland (Md.) Edison Electric Co.'s new plant, it is interesting to know that the designing and supervising engineer is a man who began at the lowest rung of the ladder and has been employed by but one electric company since entering the engineering field.

His school days were few, and owing to the death of his father, he was obliged to go to work at an age when he should have been at play. He knew what it was to go out in winter weather with his toes sticking out at the ends of his shoes, and life at times was far from being rosy.

But he possessed qualities that make for success—ambition, a determination to make good and a love for his work. Realizing that his lack of education was a

serious handicap to advancement, he completed a course in a correspondence school, at the same time performing his daily duties.

When the demand for a new plant came he was in a position not only to superintend its erection, but to assume the responsibilities of a designing engineer. As to how well the work has been done, the plant speaks for itself. It is a credit to any mechanical engineer and an indication of what a man can do when he sets out to accomplish a given work.

Removable Covering for Boiler Joints

At the recent semiannual hearing before the Massachusetts Board of Boiler Rules a member of the Boiler Inspection Department of that state proposed that all lap joints on pressure vessels be provided with removable coverings, which the owner is to remove at every called-for inspection. The proposal is commendable, and its only shortcoming is that it stops at lap joints; it should include all kinds of boiler joints.

True, lap joints are the most dangerous, but butt-strap joints are by no means immune to fracture or the troubles so frequently experienced with lap joints. Then too, there are many lap-joint boilers in service—far more, perhaps, than boilers of butt-strap construction. Then one whose sole object is public safety should not begin a good job half well. Let the proposed amendment be amended to include all classes of boiler joints and then become law.

Safety engineering should be conducted like preventive medicine, and to see and feel a boiler joint at every inspection or at least once a year would undoubtedly lead to the discovery of many defects in time to prevent serious and probably fatal results.

German Power-Plant Costs

It is frequently explained that Germany can afford to use a better class of equipment than we, because of the lower cost of the equipment and the greater value of the fuel that it saves; that Germany cannot afford to use mechanical stokers, coal-handling and other labor-saving machinery, etc., as freely as we do, because labor is so cheap that it does not pay to save it; that the more rapid adoption of the Diesel and other forms of internal-combustion engine in Germany is due to the higher cost of fuel.

The estimates of installation and maintenance costs of power plant on page 714 are interesting in this connection, and we shall be pleased if they bring out comment and comparative American figures. It must be remembered that the estimate deals with a coal-mining plant and the price of the coal is the cost price at the mine; but just what may be comprised in this *Selbstkostenpreis* is not apparent. A dollar would be considered a fair estimate, in the American bituminous fields, of the cost of putting a long ton of coal onto the car. The heat value of the German coal referred to is 12,600 B.t.u. per pound.

A recent article in *Engineering* gives the present price for "coal" in Germany as equivalent to about $4.50 per short ton "delivered in the house"; $4.33 in lots of not less than a ton "to basement." The price for "anthracite nuts" is given as the equivalent of $7.35 per short ton.

These are war prices, increased during the past year from those fixed by commissions of leading coal-mine owners, heads of big industrial concerns and large and small dealers. For retail domestic prices they do not appear to be materially different from those to which Americans are accustomed in times of peace.

The cost of the boilers will appear high to American engineers, even though the price quoted includes installation and accessories. The cost of steam per thousand pounds is no higher than the common American estimate, although here again it must be remembered that they are using their own coal. Compare the costs of the other equipment and of attendance with your own and others of which you know, and let us have the results for discussion.

Carbon Lamps in Isolated Plant Service

Some engineers seem thoughtlessly to cling to the carbon incandescent lamp even where quality of illumination and high efficiency mean something.

When the central-station solicitor secures permission to inspect the isolated-plant with a view of presenting a proposition for service, it is dollars to doughnuts that no such little point as the use of 3.5-watt-per-candle lamps, where 1-watt-per-candle units or less will fill the bill, is likely to escape his scrutiny. While the central stations can purchase tungsten lamps of the highest quality, the isolated plant's money should be as good as that of anyone else so far as it goes, and with the right kind of coöperative effort first-class lamps should be available. The electrical-supply dealers are ready enough to sell lamps to the isolated plant, and it is the latter's own fault if through insufficient testing or poor specifications, the life and efficiency results justified by the state of the art are not attained. Several isolated plants, by clubbing together should be able to get low prices.

Carbon lamps may seem justified where the cost of energy taken in connection with exhaust-steam heating is too low to warrant bothering about a few watts of lamp efficiency. This is the wrong point of view, as service is the final test. In the electric sign and in many other applications, the superiority of the tungsten lamp should as a rule preclude the use of anything less efficient. The plant owner should be encouraged to get away from the dullness of the carbon lamp, even at the cost of some effort on the part of his engineer.

Every energetic plant engineer desires to give his employer as good and as efficient service, if not better, than could be rendered by the central station, and it should not be forgotten that the more the engineer accomplishes in the direction of increasing the efficiency and raising the standards of service for the same outlay, the closer his job runs to permanency and the welcome appreciation of his employer.

After a preparatory course of 25 years at Government expense, Edward W. Parker, formerly chief statistician of the United States Geological Survey, is now to take charge of the Anthracite Bureau of Information, maintained by the anthracite-coal-mining operators.

Correspondence

Laundry-Plant Experiences

The laundry plant of which I have had charge for the past five years has been in operation for over twenty years and is somewhat antiquated. One of my recent experiences was with the main belt, which got wet from a leak in the roof during a severe rain storm and jumped off, tearing itself on one side in five places. The illustration shows how it had to be laced at these places in order to

BELT TORN ON SIDE REPAIRED WITH LACE

make it serviceable until a new belt could be procured. The accident caused a shutdown for about one hour and a half.

The blowoff pipe started to blow pretty badly at the elbow one Saturday night, and it was found that the threads were nearly all eaten away from the pipe and fitting. The service required of this boiler is practically continuous, so that repairs had to be made during the "wee sma" hours of the night, and as there were no supply houses open it was necessary to "rob" a 2½-in. water line of an elbow with which to repair the blowoff. After considerable difficulty and sundry more or less relevant language, the job was done. It was considered a lucky thing the failure did not occur when there was no one about, as the fire is banked so as to keep steam during the latter part of the night without an attendant.

This suggests an expression of opinion from readers as to the dangers incidental to leaving boilers with a heavy bank of fire at night. Is it a safe practice?

Chicago, Ill. JOHN CRETTOL.

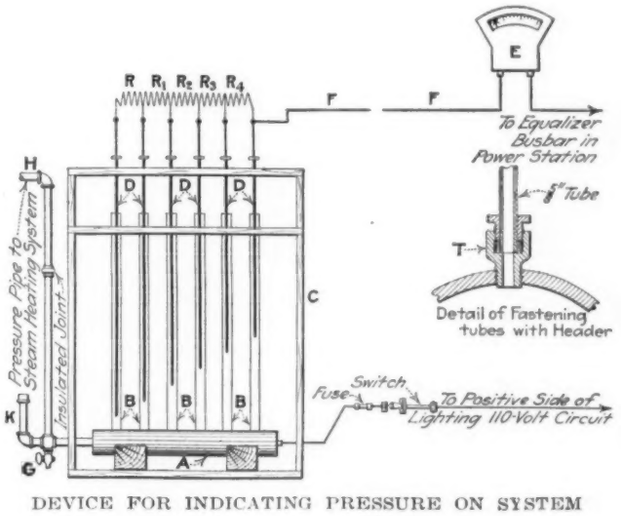
Home-Made Pressure Indicator for Heating System

Some years ago I had charge of a combination electric-light and exhaust-steam-heating plant in the East. The load center of the steam-heating system was over a mile from the power plant, and for the first three-fourths of a mile no customers were taken from the line. The load had increased so that the main pipe line was inadequate and excessive pressures had to be maintained at the power plant. The company's office was situated at about the center of the load. It was decided that with a pressure of 5 lb. at the office, a pressure of 2 lb., which was considered sufficient, would result at the extreme ends of the system. The residences of some large consumers were situated at the end of some of the branches, and they were strenuous "kickers" when the pressure dropped in the early morning during cold weather. The plant engineers naturally did not like to carry any higher back-pressure than was needed. After the office was opened at 8 a.m., one of the clerks watched the steam-heating pressure gage, and telephoned to the plant whenever the pressure dropped below 5 lb. This method, while fairly satisfactory, did not cover the critical period between 6:30 a.m. and 8 a.m. When the pull on the heating system was most severe, the plant engineer had no means of ascertaining the really important factor—the pressure at the center of distribution.

At first one of the office force was required to report at 6 a.m., much to his disgust. As no instrument on the market would serve the purpose, we decided to manufacture one.

It was soon found that the medium of transmission would have to be electricity. The plant lighting service was 220-volt three-wire direct-current. Fortunately, between the office and the plant were four old pressure-indicating wires not in use. After some experimenting the instrument illustrated was developed.

A piece of 3-in. brass pipe A about 20 in. long had a cap screwed on each end. One cap was tapped for a ½-in. pressure pipe connected to the steam-heating main, containing an insulated joint, a brass pet-cock G and a filling connection K. Glass tubes B ⅝ in. diameter and about 24 in. long were connected to reservoir A and left open at the top. This connection T is shown in the detail. Into the top of each tube was inserted a ⅛-in. brass rod D, which was adjustable vertically. The whole



DEVICE FOR INDICATING PRESSURE ON SYSTEM

was mounted in a substantial wooden frame C having a hinged front provided with a lock to keep curious persons from tampering with the apparatus. The other cap of the tube was connected through a switch and fuse to the positive side of the lighting circuit. R, R_1, R_2, etc., are porcelain wire-wound resistance-tube units, each of from 500 to 1,000 ohms and all mounted on a small frame. The line F leads from the office to the power-plant switchboard, where the voltmeter E was placed. One voltmeter terminal was connected to F and the other to the station equalizer bus. The pipe A was filled with mercury until it just showed in tubes B, and the apparatus was ready for

adjustment. All of the apparatus except the voltmeter was located in the office.

As pressure is applied through pipe *H* the mercury rises, and when it touches the brass rod in the left-hand tube *B*, the electrical circuit is completed through all the resistance and the meter indicates one pound pressure. As the steam pressure increases, the mercury rises and touches one after another of the brass rods. The resistances R_1, R_2, etc., are then cut out and the meter pointer moves to the right. Some little adjustment was required originally, but after this was done the operation was simple and the apparatus needed little attention. Petcock *G* should be provided to drain off the mercury.

A word of caution in one respect will not be out of place. In the first attempt we soldered the caps and also the connections *T* for tubes *B* to the brass pipe *A*. The job was finished late one night, set up, adjusted and left on the line. The next morning the office was filled with steam, and about $5 worth of mercury was scattered artistically over the floor. The mercury had eaten the solder, and the heads on the pipe had been forced out, liberating the mercury and opening the supply pipe *H*. The apparatus described, however, operated satisfactorily and was not expensive, as most of the parts were picked up around the plant.

R. A. LANGWORTHY.

Philadelphia, Penn.

Packing for Centrifugal Pumps

For the benefit of those who are having difficulty in obtaining suitable packing for centrifugal pumps I will state that I have seen a set of packing rings of the common diagonal wedge type (as furnished by most packing manufacturers) last for six months on boiler-feed pumps of the centrifugal type. These pumps work under pressure ranging from 225 to 275 lb. The only precaution taken was to leave the gland nuts loose at the start; as an extra precaution locknuts or keepers should be used, as the vibration may work the gland loose.

Louisville, Ky. JOHN F. HUNT.

Comparison of Chimney Sizes

In the Aug. 31, 1915, issue J. C. Lathrop has an article on "Comparison of Chimney Sizes" and gives a table showing the sizes and capacities of large chimneys in various sections of the United States. About plant No. 4 of the table he says:

It is interesting to note that the stacks for plant No. 4 were designed so that 50 ft. could be added if found necessary after all boilers were in operation. To the best of the writer's knowledge this has not been made. . . . The valuable information that may be obtained from a table of this kind [published in the Aug. 31 issue of "Power"], when combined with information regarding results obtained during the operation of one or more stations, may be illustrated by considering the design of stacks for plant No. 4. If the designer could have been sure that the future addition of 50 ft. to each stack would not be necessary, a saving of thousands of dollars would have been possible on foundations, steel supporting structure, and on metal in the steel shells.

The following is from a letter of comment by Charles W. E. Clarke, of Brookline, Mass., to the author:

I note your article in the Aug. 31 issue of "Power" in reference to comparison of chimney sizes, also the last paragraph commenting on the designs of the chimneys for the South Boston Station of the Boston Elevated Railway Co. Statements in this paragraph are erroneous, and I thought possibly you would like to correct them.

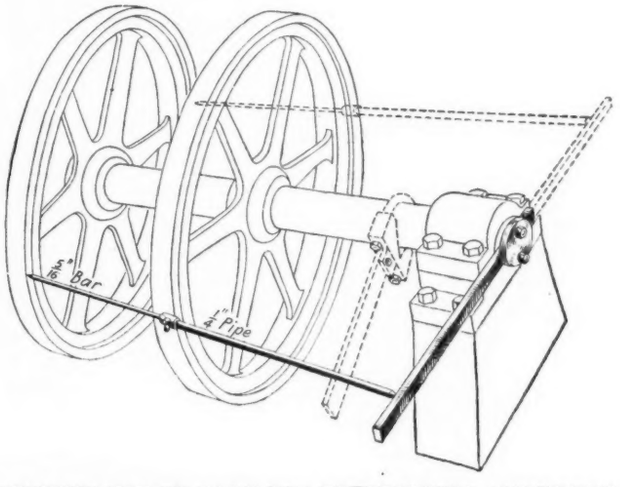
The original design, which provided for stacks 50 ft. higher than those installed, was made upon the basis of using a stoker requiring a natural draft. After the work had been started and the stack structure well under way, stokers were purchased using forced draft and 50 ft. was left off the top of the stacks with the idea that if the change were made to the natural-draft stoker at a later date, proper intensity of draft could be provided.

Those who are familiar with the history of the art can point to many cases where if this comprehensive view had been taken and allowances made for just such additions, large amounts could have been saved in the end.

Alignment of Outer Bearings

The letter on "Broken Crankshafts," page 385, Sept. 14 issue, leads me to submit a description of a simple device used by the field men of the Joseph Reid Gas Engine Co., of Oil City, Penn. In the oil country many engines are set on timber foundations, and crank failures occur of the nature shown in the item referred to, with a consequent claim in many cases that the shaft was defective. To make it possible to quickly determine the alignment, the method herewith shown was developed.

Referring to the sketch, the test bar is firmly clamped in a level position between the end of the shaft and the



SHOWING USE OF GAGE FOR DETERMINING ALIGNMENT

shaft cap. One end of the gage is then inserted in the hole in the test bar that will most nearly permit it to be used at a right angle with the bar (the test bar having several holes in it for that purpose), and the gage is set so that it will just touch the farther wheel. The shaft is then turned through 180 deg. and the test repeated. If the gage touches the wheel alike in the two positions, it proves that the outer bearing is in line in a horizontal direction. If there is any variation, however, in the distance between the test bar and the wheel in the two positions, the outer bearing must be adjusted until the two positions gage the same. After the outer bearing has thus been adjusted for the horizontal position, the shaft is given a quarter turn and the test bar is brought to a vertical position. Measurement is then made between the test bar and the top of the wheel, and if this is found to be the same as for the other position, the outer bearing is in proper alignment; if not, the bearing must be raised or lowered, as may be required to bring the distance at the top the same as on the sides.

Some crankshafts have pump cranks bolted to the ends, in which case the bar as shown is not used; but instead, the V-slot and U-bolt, as indicated in the dotted lines,

are employed, making it unnecessary to take off the pump crank or pulley on the end of the shaft.

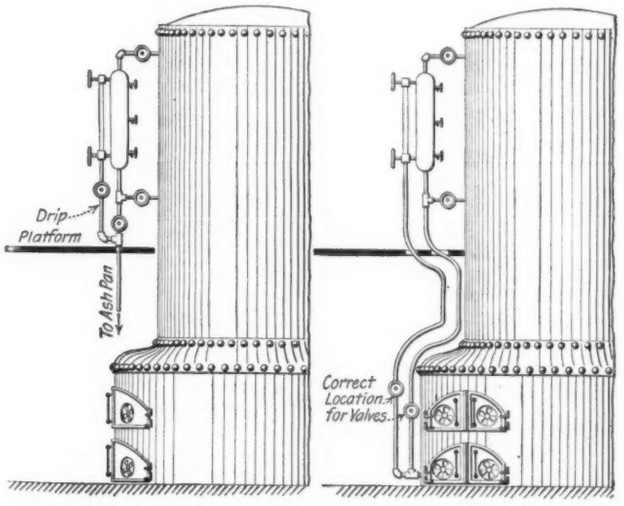
Our field men have orders to carry these outfits and test the alignment wherever permitted, and they have proved very convincing devices. To show how bad conditions sometimes are, it may be stated that one large user having 128 engines was found to have over 50 per cent. of his shafts out of line, varying from ⅛ to ⅜ in.

Oil City, Penn. JOHN REID.

Piping Water Columns

In a plant with vertical boilers the fireman was badly scalded, and one of his eyes was injured by the explosion of the gage-glass while blowing down the column, and he is in the hospital in a critical condition. It had previously been suggested that the column piping be rearranged so as to blow it from below, on the ground floor, instead of going upon the platform as shown at the left in the illustration. About a year ago the fireman got a slight scalding and a cut in the same way.

The column on a horizontal boiler is usually piped with the blowoff valve down alongside of the furnace so that the glass is at a safe distance. At the right are



RIGHT AND WRONG WAY TO PIPE WATER COLUMNS

shown the column blowoff lines on a vertical boiler extended and the valves placed within easy reach from the ground floor.

LUKE MARIER.

Fall River, Mass.

Gas-Engine Crankshaft Trouble

A recent article in *Power* on a broken crankshaft recalls a job I once had on a 125-hp. three-cylinder vertical gas engine direct-connected to a 75-kw. generator. A serious shaft crack was discovered running around the fillet of the crank on the generator end, and it was decided to replace the shaft. Upon dismantling the engine, both main bearing boxes were found to be in very bad condition and were rebabbitted at the time.

When the new shaft and bearings were put in and keyed up, trouble was experienced with the main bearing on the generator side running hot at the extreme outer edge, it being impossible to run over five minutes without the box becoming extremely hot at this point. The wedge was slackened back, but without helping matters. At the cost of considerable time and labor the box was then scraped to a fit in position, but still it ran hot on the outer edge. Finally a level was tried on the shaft and engine, and the outboard bearing showed low. It took a $\frac{3}{16}$-in. liner under the outboard-bearing pedestal to bring the shaft level. After it was brought up, the shaft was rekeyed in its bearings and the main bearing ran cool, with only an ordinary amount of slack.

The accompanying sketch shows the point of trouble. The outer bearing, being low, allowed the weight of the

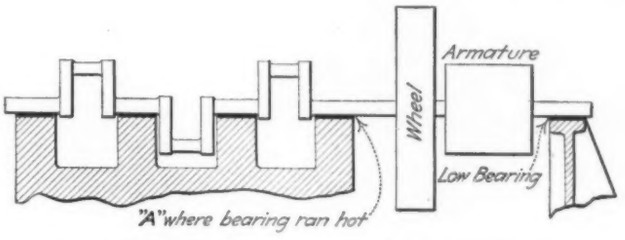


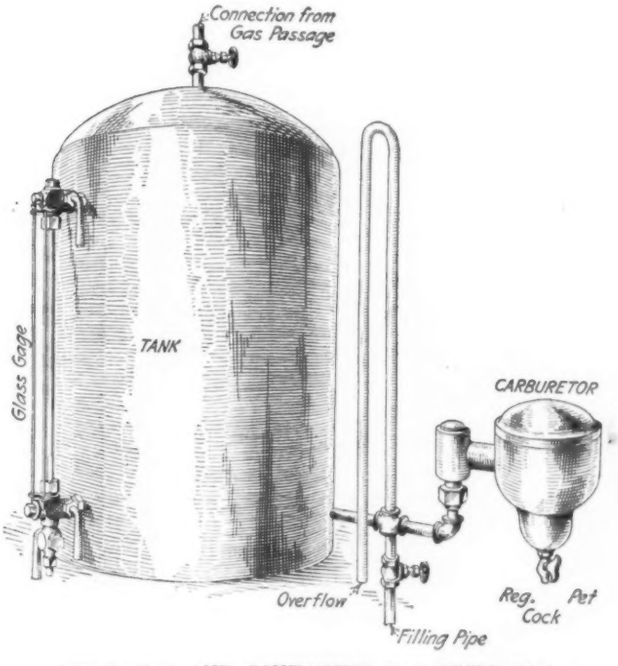
DIAGRAM SHOWING WHY BEARING RAN HOT

wheel and the armature to spring down the shaft, thus pinching hard at *A* and causing it to heat. The continual flexure, due to this bearing being so low, may have been the cause of the fracture in the old shaft.

Pittsburgh, Penn. D. N. MCCLINTON.

Flue-Gas Sample Collector

The illustration shows how I made a flue-gas collector. A 5-gal. galvanized can with a ¼-in. nipple soldered in the top was connected with a ¼-in. pipe to the space just above the tubes in the front of horizontal return-tubular boiler where the gases pass to the uptake. At



ASPIRATOR AND CONTAINER FOR FLUE GAS

the bottom of the tank I made a ¼-in. water connection and an overflow, so that water could run out when the tank was full.

I had an old Schebler carburetor which I put at the bottom of the tank on one side, after stopping its air inlet. This carburetor has a cork float attached to a needle

valve, which keeps the water at a constant level, no matter how high or low the water is in tank, as shown by the gage-glass. The collector is first filled with water, then the gas passage is opened and the drain-cock at bottom of carburetor is regulated so that most of the water in the tank will run out during a 12-hr. shift. I then have a good sample of gas to analyze for CO_2, CO and O.

South River, N. J. JOHN MORLOCK.

The S.-T. Uniflow Engine

I have been greatly interested in the various articles that have appeared in *Power* during the past year relating to the una- or uni-flow engine, and particularly in the reasons given as explaining the excellent economy in this type of cylinder. In your issue of Nov. 2 is a description of the S.-T. uniflow engine, and in reading this some questions come to mind as to whether this cylinder can give much, if any, better economy than a counterflow.

Previous articles indicate that the economy of the uniflow cylinder results largely from the exhaust following the piston and not flowing back across the relatively hot portion of the cylinder. In the S.-T. engine probably 35 or 40 per cent. of the exhaust steam must flow back to the center of the stroke section, thus cooling the sleeve and a portion of the cylinder. Further, the cool sleeve moves back to the hot end of the cylinder, with a cooling influence on both the cylinder and the steam that is being compressed. Will not the effect of this be detrimental to steam economy?

What is the effect of the sleeve on clearance? The sleeve must be thick enough to be substantial. The difference between the diameter of the piston and of the cylinder will necessitate a greater volume of steam, and the movement of the sleeve will cause the pressure to drop more rapidly during expansion than in an ordinary cylinder. Will not this affect the economy unfavorably?

In the last paragraph of the article we read:

"By setting the sleeve a slight distance behind the piston the latter can be made to reach the end of the stroke in advance of the sleeve with the result that release would be later in the stroke and the exhaust port would remain open for a longer interval. . . . The more complete the exhaustion the smaller may be the clearance."

If my understanding is correct the cylinder provides an amount of clearance undesirable with high steam pressures such as used in locomotives, and I do not see how this clearance can be eliminated. Further, if the piston reaches the end of the stroke in advance of the sleeve, even though only a trifle, will not the sleeve, and therefore the cylinder, have to be lengthened just that much, with the result of increasing the clearance?

From a mechanical standpoint is the sleeve entirely practicable? It is customary to build a cylinder with a counterbore so the piston will overrun the main bore and keep the wear uniform. Can a counterbore be used in the sleeve, especially as it is proposed to vary the motion of the sleeve with reference to that of the piston and this will result in changing the length of travel of the piston through the sleeve? Perhaps the variation will not be sufficient under even extreme conditions to keep the piston from overrunning the ends of the sleeve.

This letter is not a criticism, but a request for information, and as many others of the readers of *Power* may be interested in the same questions, it is hoped you will publish an explanation. Results from an actual steam-rate test would be interesting. A. A. WHITNEY.

Philadelphia, Penn.

Some Notes on Thermometers

In reading the article, "Some Notes on Thermometers," by S. S. Rathburn, in *Power*, Oct. 12, p. 509, I had brought to mind an instance in which a very considerable and important error resulted from using armored thermometers.

Acceptance tests were being made on a large steam turbine, its condenser and auxiliaries. The air and vapor from the condenser passed through a cooler on the way to the dry-air pump. The air temperatures before entering and on leaving the cooler were among the readings to be taken. It was found that the temperature reading of the air after passing through the cooler was higher than on entering. For example, the reading of the air on entering the cooler varied from 97 to 99 deg. F., while on leaving it was found to be from 106 to 109 deg. F. The reason for this was discovered when bare thermometers were used, the temperature drop in the air in passing through the cooler being then from 2 to 5 deg. F. The armored thermometer measuring the temperature of the air leaving the cooler was within a few inches of a steam line carrying high-pressure steam to the auxiliaries, and the heat absorbed by the armor on the thermometer was quickly conducted to the bulb, causing the temperature to read from 10 deg. to 15 deg. F. too high.

Of course it is evident from the small temperature drop of the air in passing through the cooler that the latter was not efficient, but this might well be due to the fact that the water used for cooling the air from the condenser was also cooling the warm air in the vicinity of the high-pressure steam line. HAZEN G. TYLER.

Brooklyn, N. Y.

Turbine Examination Questions

In a letter by Webster Leonard on "Turbine Examination Questions," in the Oct. 26 issue, I notice that in the reply to question 14 as to how many stages a Terry turbine has, Mr. Leonard says that the noncondensing has one, the condensing two. This reply is correct in regard to the noncondensing turbine, but is slightly incorrect as to the condensing turbine.

The two-stage condensing turbine which Mr. Leonard had in mind is a type that was particularly adaptable to the low speeds of the driven apparatus at the time when this turbine was used. Instead of manufacturing this type the return-flow, composite design is now made.

This machine consists of two distinct elements, a high-pressure and a low-pressure. The former element consists of one pressure stage in which the steam is expanded from boiler pressure to about atmospheric. In the low-pressure element there are a number of pressure stages. The number is determined by the steam conditions and depends on whether the vacuum is low or high.

For a further description of this type I would refer Mr. Leonard to the Mar. 30, 1914, issue of *Power*.

J. BRESLAV,

Hartford, Conn. The Terry Steam Turbine Co.

Inquiries of General Interest

Piston Displacement of Engine—What would be the piston displacement of a 12x18-in. engine with a 2½-in. piston rod, when running at 220 r.p.m.? R. C. L.

The gross area of the piston would be $12 \times 12 \times 0.7854 = 113.1$ sq.in., and as the area of the piston rod would be $2\frac{1}{2} \times 2\frac{1}{2} \times 0.7854 = 4.9087$ sq.in., the net area of the piston on the crank side would be $113.1 - 4.9087 = 108.1913$ sq.in. Hence the piston displacement per revolution would be $(113.1 + 108.1913) \times 18 = 3{,}983.2434$ cu.in., and for 220 r.p.m. would be $3{,}983.2434 \times 220 = 876{,}313.548$ cu.in., or $876{,}313.548 \div 1{,}728 = 507.13$ cu.ft. per min.

Estimating Heating Surface in Wall Coil—How is the heating surface estimated of a wall coil made of 1-in. steam pipe? R. J. M.

The heating surface usually is based upon the superficial area of the pipe, neglecting the small increase of surface due to fittings. The outside diameter of 1-in. steam pipe is 1.315 in., and the external circumference is 4.131 in., therefore each foot of pipe has $\frac{4.131 \times 12}{144} = 0.344$ sq.ft.; that is, $\frac{1}{0.344} = 2.906$ lin.ft. of 1-in. pipe is required per square foot of heating surface.

Inductance in Circuit—If a 60-cycle alternator is connected to a circuit that has an inductance of 0.08 henry and resistance of 15 ohms, what e.m.f. must be supplied by the alternator to force a current of 15 amp. through the circuit? H. C. M.

This problem may be solved by the formula,

$$\text{e.m.f.} = \sqrt{(IR)^2 + (2\pi f LI)^2}$$

where I is the current flowing (15 amp.); R the ohmic resistance (15 ohms); f the frequency in cycles per second (60); and L the inductance (0.08 henry). Substituting,

$$\text{e.m.f.} = \sqrt{(15 \times 15)^2 + (2 \times 3.1416 \times 60 \times 0.08 \times 15)^2} = 452.6 \text{ volts.}$$

Hardness of Water—What proportion of calcium carbonate or calcium sulphate must be contained by a water to be designated "hard" water? J. R. C.

The designation "hard" is a general term, having specific meaning according to the particular use made of the water. For that reason hardness is generally stated in degrees, and the allowable degree for any given use is specified. According to Clark's standard, a degree of hardness consists of the presence of one grain of calcium carbonate, or its equivalent of another calcium or magnesium salt, per "imperial" gallon of 70,000 grains of water. The American standard is one grain per United States gallon of 58,381 grains of water, and for boiler use water is considered hard if it contains more than 8 grains of the salts to a gallon.

Factor of Evaporation with Superheated Steam—When steam is generated at 150 lb. gage pressure with 100 deg. superheat from feed water at 180 deg. F., what is the factor of evaporation for equivalent evaporation from and at 212 deg. F.? W. L. J.

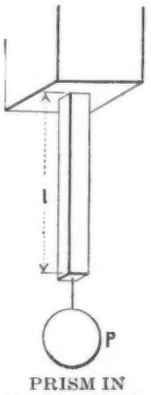
With feed water supplied at 180 deg. F., each pound of feed water would contain 180 — 32, or 148, B.t.u. above 32 deg. F., and when raised to steam at 150 gage, or 165 absolute, with 100 deg. of superheat, each pound (weight) of the steam, as found from the steam tables, would contain 1,252 B.t.u. above 32 deg. F. and each pound of the feed water for conversion into steam would receive $1{,}252 - 148 = 1{,}104$ B.t.u. The heat required for the evaporation of a pound of water from and at 212 deg., or the latent heat of evaporation, is 970.4 B.t.u., and therefore the equivalent evaporation from and at 212 deg. F., or factor of evaporation, would be $\frac{1104}{970.4} = 1.1376$.

Value of h in Formula for Factor of Evaporation—In the formula, $F = \frac{H - h}{970.4}$, for "factor of evaporation," where H = the total heat above 32 deg. F. of 1 lb. (weight) of steam at the observed pressure, h = the total heat above 32 deg. F. of 1 lb. of the feed water, and 970.4 = the heat of vaporization, or latent heat, of steam at 212 deg. F., is the value of h to be taken after the feed water has been heated by an economizer or feed-water heater, or before any such heat has been added? G. F. S.

The factor of evaporation applies to the heat added to the water as received by the boiler, and therefore h in the formula applies to the condition of the feed water after leaving a feed-water heater or economizer, and should be taken with reference to the actual temperature of the feed water as it enters the boiler. Although h represents the total heat above 32 deg. per pound of feed water entering the boiler and for strict computations the value of h should be obtained from the steam tables, for ordinary temperatures of feed water the number of B.t.u. above 32 deg. F. is so nearly identical with the temperature above 32 deg. F. that, in using the formula, it is customary to employ the sensible temperature minus 32 for the value of h.

Coefficient (or Modulus) of Elasticity—What is the coefficient of elasticity of a material? W. R. J.

If a prismatic bar whose section and length are unity be compressed or elongated any amount within the elastic limit of the material, the quotient obtained by dividing the force that produces the displacement by the amount of compression or extension is called the coefficient, or modulus, of elasticity. This is usually expressed by the letter E.



PRISM IN ELONGATION

Referring to the figure, let K = section in square inches of a prismatic bar whose length is l, and g = the elongation (or compression) in inches caused by a force P in pounds applied longitudinally. Then $\frac{P}{K}$ = force on a unit section, and $\frac{g}{l}$ = the elongation or compression for a unit of length, from which,

$$E = \frac{P}{K} \div \frac{g}{l} = \frac{Pl}{Kg}$$

The coefficient E is not exactly, though for most materials it is nearly, the same for compression as for extension.

Computation of Boiler Steam Space—A horizontal return-tubular boiler is 72 in. diameter by 18 ft. long, and the water line is 30 in. from the top of the shell. What is the approximate steam space in cubic feet? E. L.

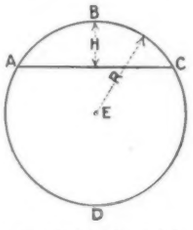


DIAGRAM FOR COMPUTING AREA OF SEGMENT

The volume of the steam space would be the segmental area of one head above the water line, in square feet, multiplied by the distance from head to head, in feet. The area of the segment is closely approximated by the formula:

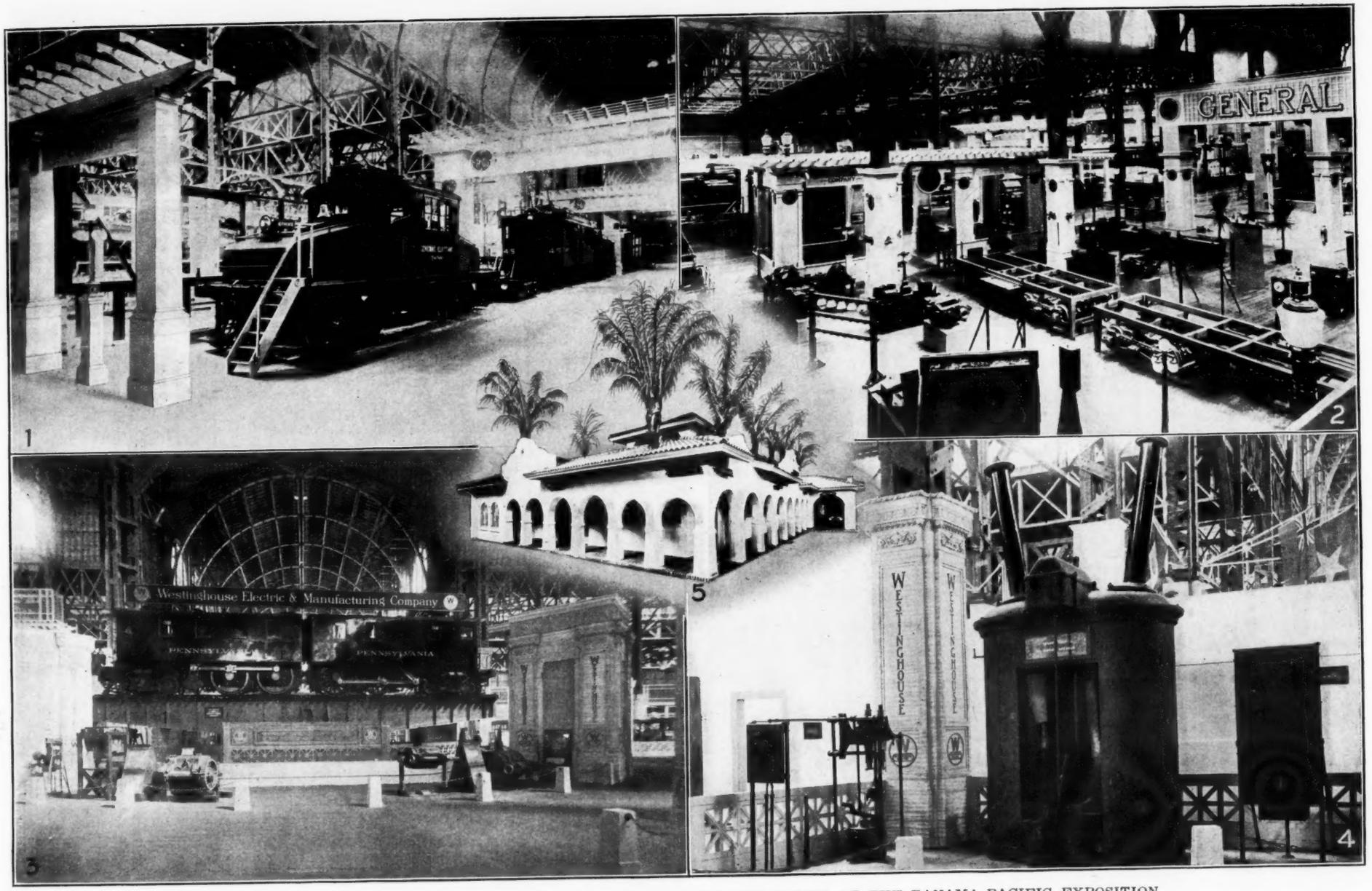
$$\text{Area of segment} = \frac{4H^2}{3}\sqrt{\frac{2R}{H}} - 0.608$$

where the dimensions of H and R are taken as indicated in the figure. Substituting H = 30 and $R = \frac{72}{2}$, or 36, then

$$\text{Area of segment} = \frac{4 \times (30 \times 30)}{3}\sqrt{\frac{2 \times 36}{30}} - 0.608 = 1606.32 \text{ sq.in.}$$

or $\frac{1606.32}{144} = 11.155$ sq.ft, and allowing 18 ft. from boiler head to boiler head, the volume of steam space would be $11.155 \times 18 = 200.79$ cu.ft.

[Correspondents sending us inquiries should sign their communications with full names and post-office addresses. This is necessary to guarantee the good faith of the communications and for the inquiries to receive attention.—Editor.]



EXHIBITS OF THE GENERAL ELECTRIC AND WESTINGHOUSE COMPANIES AT THE PANAMA-PACIFIC EXPOSITION

1—General Electric locomotives. 2—G. E. railway exhibit. 3—4,000-hp. 600-volt Westinghouse locomotive. 4—A 165,000-volt 300-amp. oil circuit-breaker. 5—The Home Electrical

Panama-Pacific Exposition--IX

SYNOPSIS—Illustrations and brief descriptions of the exhibits of the Westinghouse, General Electric, Lagonda Manufacturing, Pennsylvania Flexible Metallic Tubing, American Steam Pump, York Manufacturing, Crane and Lunkenheimer companies.

The Westinghouse companies have three exhibits: One in the Transportation Palace, which is their headquarters; one in the Palace of Machinery; and two kinds of locomotives, one of the trolley and one of the storage-battery type, in "The Mine" in the Mining Building. They have also a great many motors driving machinery of all kinds all over the grounds, in the Palaces and on the Zone. The principal installation upon the Zone consists of nine motors aggregating about 100 hp., operating the aëroscope.

In the Transportation Building the exhibit consists principally of railway equipment, starting, lighting and ignition sets for automobiles and motor vehicles, storage-battery charging outfits, trolley-line material, etc. The central feature is a large electric locomotive mounted on a turntable twelve feet above the level of the floor and revolving once in about four minutes.

The Record Oil Circuit-Breaker

Also in the Transportation Building is a group of panels showing a complete line of carbon circuit-breakers used in industrial-power service. One 24-in. panel contains two 9-in. indicating switchboard meters, as used previously by the majority of central stations. For comparison there are shown upon the same-sized panel three 7-in. instruments, as used in more modern practice. Another panel contains a 4-contact circuit-breaker for 10,000 amp. at 750 volts. These are built by the Westinghouse Electric Co. up to 24,000 amp. There is also shown a complete exciter reverser and feeder panel for a 2,200-volt circuit, with a complete line of 7-in. instruments, including synchroscope and synchronizing lamps on bracket arms. An extra panel contains the latest type of Westinghouse voltage regulator, which although upon the market only for a few months, has been tested out and installed successfully in 38 states and in Canada. The merit of this regulator consists especially in the very wide range of voltage. The omission of the d.-c. control coil makes the regulator independent of the excitation voltage. The voltage range from residual to maximum exciter voltage can be obtained. There is also shown a 165,000-volt 300-amp. oil circuit-breaker which is said to be the largest ever built, and a 35,000-volt of the same type. The steam turbine and condenser referred to elsewhere, as well as a model of the Melville-McAlpine reduction gear and a line of industrial motors, are comprised in the Machinery Palace exhibit.

The headquarters of the General Electric Co. are in the "Home Electrical," a complete dwelling, garage included, inside of the Palace of Manufactures, and fitted with electrical devices for doing everything conceivable. It has no aggregated exhibit of power apparatus and nothing suggestive of the fact that it makes steam turbines in the largest capacities, internal-combustion engines, etc. A 1,000-kw. motor-generator set and a 250-kw. balancing set in the Manufacturers' Building, and another combination of the same capacity in the Food Products Building supply current for the searchlights that illuminate the Tower of Jewels. It supplies all the working high-current transformers and all the transformers for the Manufacturers' Palace. There are upward of 300 General Electric motors working other exhibits, including the Panama Canal and the Grand Cañon on the Zone.

The General Electric Company's Contributions

For the complicated machinery of the large working model of the Panama Canal this company also furnished the control system, as well as the switchboards in the Pelton-Doble, McIntosh & Seymour, exhibits in the Machinery Hall and the Sperry Flour Mill in the Food Products Building; also the motor-generator sets for the forty-eight 36-in. scintillators on the pier, these being used largely for illuminating effect, especially throwing floods of colored light upon smoke bombs and clouds of vapor. The most extensive single exhibit of this company is in the Transportation Building, where electric locomotives for various classes of service from underground mine haulage to heavy steam-railroad electrification railway motors, storage-battery trucks, signal devices, etc., are shown. The General Electric Co., through its lighting expert, W. D'Arcy Ryan, was largely instrumental in the production of the artistic and effective illumination of the grounds and buildings. The influence and products of this company are so pervading and diffusive that it is impossible to particularize to an extent that will bring out their aggregate magnitude.

In the larger valves and apparatus for the transmission and control of steam, the Crane Co.'s exhibit is practically alone. Prominent features are a 72-in. hydraulically operated gate valve, a 24-in. cast-steel electrically operated gate valve, a 48-in. atmospheric-exhaust release and back-pressure valve, a working exhibit of Crane-tilt steam traps, demonstrating the nonreturn, three-valve, lifting and direct-return types, sectioned samples of pop safety valves, separators and other specialties mounted upon revolving columns, a line of brass globe and gate valves, with sectioned samples of all weights and sizes, also cases of small fittings—brass, malleable and cast-iron. The main gateway is made as shown in the photographs, of pipe bends and steel and welded headers, the front being cut off by gate valves on one side and fittings on the other, from 18-in. down to 2-in. The gateway on the north side is made of drainage fittings and pipe bends. Automatic stop and check valves and other cast-steel valves of different sorts are shown. The east side is made up of pipe bends, an ammonia separator, ammonia condenser, etc.

Small Valves and General Fittings

In the line of small valves, fittings, etc., the Lunkenheimer Co. has the field practically to itself. Its space contains a sample of practically everything in its long line of products, from miniature check valves for gasoline to the 24-in. iron gate valve which marks the corner of the exhibit. Several of the larger valves are sectioned and mounted upon rotary stators. The company has also a very effective exhibit at San Diego, where it is the only

EXHIBITS OF THE GENERAL ELECTRIC [illegible]. 1—General Electric locomotives. 2—G. E. railway exhibit. 3—4,000-hp. 600-volt Westinghouse locomotive. 4—A 165,000-volt 300-amp. oil circuit-breaker. 5—The [illegible]

SOME OF THE POWER-PLANT APPARATUS EXHIBITS AT THE PANAMA-PACIFIC EXPOSITION

1—The American Steam Pump Co. 2—The York Manufacturing Co. 3—The Pennsylvania Flexible Metallic Tubing Co. 4—The Lagonda Manufacturing Co.

exhibitor except the National Harvester Co. in the engineering line.

The exhibit of the Lagonda Manufacturing Co. is shown in panel 4, on page 732. To the left are the high-power direct motor-driven tube cleaners for boilers, condensers and economizers, suspended and inserted in condenser tubes, and the tubes of a B. & W. manifold. Directly behind these can be seen the handwheels of outside and internal dashpot automatic cutoff and nonreturn valves. At the back of the exhibit and to the extreme left is shown a device by which the entire operation of cleaning a Stirling boiler may be conducted from outside of the drum. To the right of this and to the left of the booth are shown the electric and air or steam motor-driven reseating machines for reseating and grinding the fitting surfaces of and cleaning scale and soot from the caps and nuts of B. & W. and similar-type boilers. To the right of the entrance of the exhibit is a stand containing a full display of all types of water, air and steam turbine-driven cleaners for water- and fire-tube boilers, condensers and other tubular apparatus, also cleaners for curved-tube boilers. On a second stand directly behind these are exhibited Lagonda tube cutters and a sectional model of the type A automatic cutoff valve showing the construction and operation of the valve and external dashpot. Behind this is the Lagonda grease extractor and a three-basket multiple strainer, arranged with glass panels so that the flow of the water and the retention of refuse, as well as the cleaning operation, may be observed.

Refrigerating Machinery Exhibit

The exhibit of the York Manufacturing Co. in the Palace of Food Products is shown in panel 2, of page 732. It contains one double-cylinder 20-ton vertical single-acting inclosed-type ice machine driven by a 35-hp. Westinghouse motor; one complete high-pressure side; one 20-ton shell and tube brine cooler located back of the condensers; one Smith-Vail 5½x8-in. triplex brine pump driven by a 7½-hp. Westinghouse motor; one Smith-Vail 4x6-in. triplex water pump driven by a 5-hp. Westinghouse motor. In front of the condensers there is a 4-ton double-cylinder inclosed-type refrigerating machine belted to a 7½-hp. Westinghouse motor. The load conditions are such that a 20-ton machine will be too large at times, and the 4-ton machine is connected up to the plant and operated during light-load periods. The still exhibit consists of one York 1915 automatic 300-lb. can dump, a frosted pipe railing, numerous valves, fittings, headers, etc. The Pacific Ammonia frosted pipe sign was also furnished from their factory.

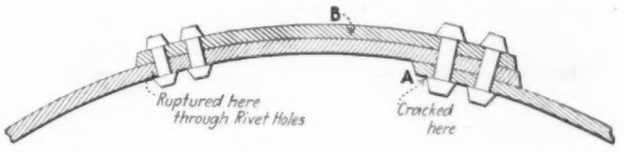
The Pennsylvania Flexible Metallic Tubing Co. exhibits a line of metal hose for high pressure. Sectioned portions show the construction, and the exhibit comprises sizes from ⅛ of an inch to 12 in. in diameter.

The American Steam Pump Co., panel 1, page 732, shows a line of Marsh pumps for boiler feeding, condenser and general purposes.

A Most Unusual Electrical Accident occurred recently when three linemen in the employ of the Seattle municipal lighting department were seriously burned as a result of high-tension current at 60,000 volts on the lines of the Puget Sound Traction, Light and Power Co. jumping through the air a distance of 14 ft., charging two service wires which the linemen were extending, and passing through their bodies. The weather was foggy but little wind was blowing. It is reported that the men will recover, but it is doubtful if they will ever regain the use of their hands.

Explosion of Steam Drum of B. & W. Boiler

Early in the morning of Sunday, Oct. 24, the 36-in. drum of a B. & W. boiler at the fanhouse of the Cameron shaft of the Susquehanna Coal Co. at Shamokin, Penn., exploded by the rupture of the lap-riveted seam of its middle course. The sheet was straightened out completely, the building was demolished, the steel stack was thrown high upon the hillside above the power house, and surrounding buildings were injured by flying débris. The only personal injury was that sustained by the night engineer, but that was serious.



REPAIR ON CRACKED JOINT OF STEAM DRUM

The boiler was a 125-hp. unit sold in 1891 to the Mineral Railroad and Mining Co., which has since been acquired by the Susquehanna Coal Co. Its single drum, 36 in. in diameter, was built in three courses of $\frac{5}{16}$ plate with double lap-riveted longitudinal seams, ⅝-in. rivets 2.04-in. pitch, 1.9 in. between rows, designed for 125 lb. pressure. A local boiler maker in 1904 renewed the front and rear courses, but retained the middle course which failed, strengthening it, as he supposed, by strapping as shown in the sketch. It appears that cracks had developed along the inside row of rivets on the under sheet of the lap joint (at *A* in the sketch), and thinking to hold the joint together the boiler maker had riveted on the strap *B* of ⅜ plate 10 in. in width. The rupture occurred at the same relative position along the line of rivets joining the strap to the shell. So far as we know this is the first instance of the explosion of a steam drum upon this type of boiler.

Fusible Tin Boiler Plugs*

By G. K. Burgess and P. D. Mercia

The fusible boiler plug consists usually of a brass or bronze casing filled from end to end with a fusible metal or alloy. Its function is, as its name indicates, to give warning of overheating in the boiler by fusing and blowing out. Such plugs are used in many locomotive and marine boilers in this country and the Steamboat-Inspection Service requires their installation in all boilers subject to its inspection.

Tin is generally used as the fusible material of these plugs and has many advantages, but carelessness in its use and inspection has led to boiler accidents[1] that can be traced to failure of the tin plug to function properly, and investigation of these cases and of a large number (approximately 1,100) of such plugs, both new and used, at the Bureau of Standards, has shown that unless the tin used in such plugs is pure it is subject to deterioration by oxidation when in service. The oxide has a melting point above 1,600 deg. C. and often forms in such a way as to prevent the blowing out of the remaining tin when the latter fuses.

The oxide formed may take several forms, two of which are illustrated in Figs. 1 and 2. In Fig. 1 the oxide (the dark portion) has assumed the form of a network throughout the tin, starting from the water side of the plug, whereas in Fig.

*From a paper presented before the American Institute of Metals, based on an investigation by the authors as reported in full in Technologic Paper No. 53 of the Bureau of Standards.

[1]Notably that on the steamship "Jefferson," May 11, 1914, in which several persons were killed.

2 a solid oxide mass has formed at both ends. The tin in all cases in which such oxidation has occurred is impure, containing from 0.3 to 5 per cent. of zinc and lead, and in none of the

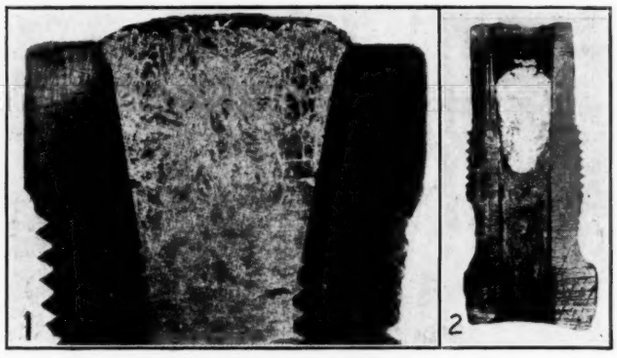


FIG. 1. NETWORK TYPE OF OXIDATION. FIG. 2. SOLID OXIDE AT BOTH ENDS

plugs examined which contained pure tin was any trace of oxidation of these types noticed. In particular, it was shown both by examination of used plugs and by service tests of plugs at the bureau that zinc in amounts as low as 0.3 per cent. may be the cause of the "network" oxidation of tin in boiler plugs.

The effect of zinc may be ascribed to the fact that it does not form a solid solution with tin, but is present as practically pure metallic zinc, which forms upon long heating, at around 180 to 185 deg. C., a coalesced network structure. Certain boiler waters (alkaline ones, for example) will attack the zinc and corrode their way into the tin, forming the honeycombed oxide structure referred to.

From the results of the investigation it is shown that pure tin must be specified for such plugs, and when such tin is used the danger of oxidation is probably entirely eliminated. The safest practice would be to specify tin to be 99.9 per cent. pure and to contain less than 0.01 per cent. each of zinc and lead, which would admit only Banca and one or more others of the purest varieties. It is, however, probable that tin of 99.8 per cent. purity, containing less than 0.01 per cent. zinc and 0.50 per cent. lead, is sufficiently pure for use in fusible plugs, and such a specification includes most of the high-grade brands of tin on the market.

A quick and convenient method of determining whether a tin sample contains amounts of impurities as great as 0.1 or 0.2 per cent. is that of the determination of its melting or freezing points. Such a method is well adapted for use whenever a chemical analysis of the tin cannot be conveniently made.

Diesel Engine Applied to Marine Purposes*

By C. Kloost

SYNOPSIS—The author reviews the performances of a list of Diesel-engined ships and discusses features of design of the engines with special reference to the "Werkspoor." Oil-fuel data are included.

The first Diesel engines for mercantile ships were started in Russia on the River Volga and the Caspian Sea and were destined for ships owned by Nobel Bros., in Petrograd. After these a few small marine Diesel engines were turned out in 1910 by Sulzer Bros., of Winterthur, and the Machinenfabrik Augsburg-Nürnberg. These were high-speed, box-frame engines of comparatively low power and did not yield much satisfaction in continued service.

DIESEL ENGINES OF THE "VULCANUS"

After the small marine Diesel engines of Sulzer and Nürnberg, the six-cylinder engine of the "Vulcanus" came as the first full-powered reversible Diesel engine. This had a capacity of 450 b.hp. at 180 r.p.m.; the cylinder bore was 15.7 in. and the stroke 31.5 in. The vessel is a 1,000-ton tank ship and the engine was built at the Werkspoor Works of Amsterdam. In the beginning trouble was encountered with the air compressors and also through the lack of experience of the engine attendants. The ship has, however, successfully completed every voyage undertaken, among others a trip from France to Singapore without an extra stoppage at sea, and it is in permanent service in India at present.

The engine of the "Vulcanus" is represented in Fig. 1. The crankshafts and guides are inclosed in a casing; the rear and side walls are made of cast iron and shut off in front by light steel sheets that can easily be removed. For the big forces tie-rods are applied, connecting the cylinder beam to the bedplate. The latter is trough-shaped to collect the lubricating oil, which is then cleaned and used over again; the oil being forced to the bearings by a pump; the motion of the camshaft is derived from the mainshaft by eccentrics and rods that work on a small crankshaft that carries a pinion. This pinion works on two gear wheels of twice the number of teeth, thus reducing the speed of the camshaft to half the engine speed.

The engine is directly reversible, there being two camshafts—one for forward and the other for backward motion. The hand-wheel for the reversing is mounted on a handle case, where all the operations necessary for starting, reversing, regulating and stopping can be controlled.

The fuel-pump arrangement presents an interesting feature. There are only two pumps, one a spare, for the whole engine. The oil is pumped into an accumulator, which stops the pump when full by keeping the suction valve open. The "Vulcanus" was first equipped with an accumulator for this purpose, consisting of two plungers in line having different gages. The smaller one worked through a stuffing-box in a cylinder containing oil, the larger one in a cylinder with air, directly connected with the air line for in-blast. The pump was automatically cut out by the motion of the plunger, and then the latter forced the oil to the cylinders. When near its end position, it brought the pump into action again. This arrangement was soon replaced by another that incorporated the same advantages and omitted the stuffing-boxes.

This arrangement is generally called the "floating vessel," which is placed high in the engine room. The bottom is connected to the delivery of the fuel pump and to the fuel-inlet valves on the cylinder and the top to the in-blast air line. It is mounted on a balance with a counterweight, in such a manner that it will sink a few inches when full of oil and rise when empty; this motion is transmitted to the suction valve of the fuel pump, which is thereby kept open or left free, as the case may be. This arrangement requires the use of but one fuel pump for the six cylinders, as the distributors work perfectly with a difference in pressure before and after the valves in the distributor equal only to the pressure of a few feet of oil column, according to the height of the floating vessel above the fuel valves.

Another advantage is the amount of fuel always ready for starting. In case a pump should get out of order, there is plenty of time to start the spare pump before the engine stops from lack of fuel.

The "Vulcanus" held for a full year the place of being the only full-powered seagoing Diesel-engine ship afloat, from the end of 1910 until the end of 1911, when the "Sembilan" came into service. This ship has a comparatively small engine—200 b.hp. in three cylinders of 15.75-in. bore and 19.68-in. stroke. In February, 1912, Burmeister & Wain, of Copenhagen, began work on the "Selandia," a twin-screw vessel with two 1,000-hp. four-stroke-cycle engines.

I will here insert some interesting results obtained with one of the later Burmeister & Wain engines. By the courtesy of this concern I am enabled to give a comparison of the Diesel ship "Siam" with the steamship "Kina." The ships belong to the same owners and the voyages are the first made by each.

*From a paper presented at the International Engineering Congress, San Francisco, Sept. 20-25, 1915.

†Technical director of "Werkspoor," Amsterdam, Netherlands.

The "Kina" is a single-screw ship of the following dimensions: Length, 385 ft.:; beam, 53 ft.; draft, 26 ft. 10¾ in.; deadweight, 8,720 tons; bunker capacity (coal), 770 tons. It was built in 1911 and is driven by triple-expansion steam engines.

The dimensions of the "Siam" are: Length, 410 ft.; beam, 55 ft.; draft, 30 ft. 6 in.; deadweight, 9,700 tons; bunker capacity (oil), 1,250 tons.

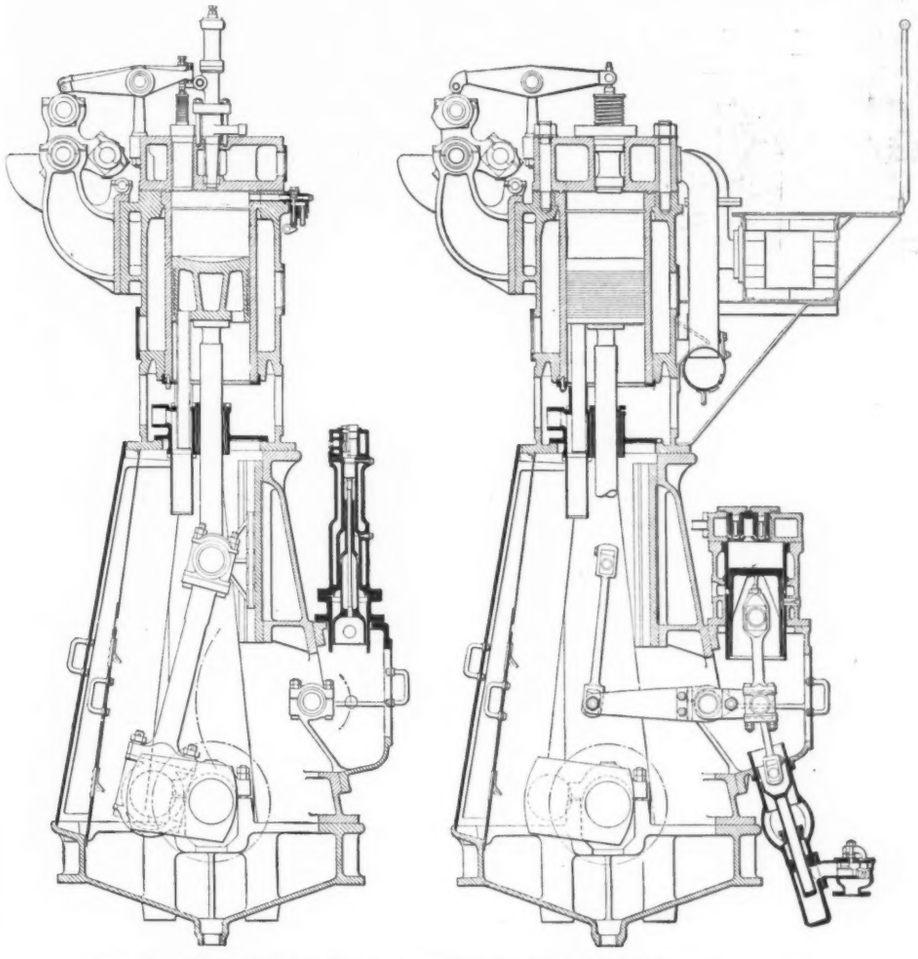


FIG. 1. SECTIONS OF SIX-CYLINDER DIESEL OF THE "VULCANUS"

The voyages made by these ships are the same, so that the results are well suited for comparison. From the engine-room reports the following data are of interest:

	S.S. "Kina" First Voyage	S.S. "Siam" First Voyage
Duration of trip	163 days	182 days
Time passed at sea, engine working	109 days	107.5 days
Time passed in harbor	54 days	74.5 days
Distance in miles	27,808	27,818
Number of hours regular running	2,517	2,497
Maneuvering	92	82
Mean speed, knots	11	11.14
Fuel consumption per mile	384.6 lb. (coal)	88.7 lb. (oil)
Lubricating oil consumption per i-hp.-hr.	0.0072 oz.	0.0577 oz.
Price of fuel per ton	$5.40 (coal)	$8.60 (oil)
One thousand tons of cargo carried one mile at a speed of 11 knots at fuel expense of	12.3c.	4c.
Total fuel expense for a cargo load of 8,500 tons for transportation from Copenhagen to East Asia and back (27,818 miles) at a speed of 11 knots	$30,300	$9,900

The engine-room attendance in the "Kina" consists of 3 engineers, 2 assistant engineers and 14 firemen, a total of 19 men; while that of the Diesel ship "Siam" consists of 4 engineers, 5 assistant engineers and 4 oil men, a total of 13 men.

Resuming the chronological line, I will now mention the "Eavestone," owned by Furness, Withy & Co. The engine was built by Richardson, Westgarth & Co., Ltd., Middlesborough, under license of Carels Frères, of Ghent; the hull was built at Raylton Dixon & Co., Ltd., of Middlesborough, and the dimensions are 276 ft. length, 40½ ft. beam, 4,500 tons displacement, 8,200 tons carrying capacity, and 9.7 knots speed. One single-acting two-stroke-cycle Carels Diesel engine was installed, having four cylinders with 20-in. bore and 36-in. stroke. It developed 800 hp. at 95 r.p.m. The first trip of any distance was crossing the Atlantic, but on the homebound voyage considerable trouble was experienced. New pistons and cylinder covers had to be sent out to continue the voyage, and upon arriving home extensive repairs were necessary. According to the most recent reports the engines have been taken out of the ship. Carels, of Ghent, have several licensees outside of Belgium, namely: Schneider & Cie, le Creusot, who built two 900-hp. Carels engines for the sailing ship "La France"; J. C. Tecklenburg, of Bremerhaven, who built a 1,500-hp. six-cylinder Carels engine for the "Rolandesck"; Reihersteig, of Hamburg, who built a 2,000-hp. six-cylinder Carels engine for the "Wotan"; the Clyde Engineering and Shipbuilding Co., of Glasgow, which built the engine for the "Fordonian," also a Carels two-stroke-cycle type. The Carels Co. itself has built one or two engines for the British Admiralty.

In 1912 many Diesel-engined ships were put in commission. Outside of those already mentioned there are the "Juno" with 1,110-hp. Werkspoor engines and the "Emanuel Nobel" with two such engines; both are tank ships. They represent the present-day Werkspoor marine Diesel engine (see Fig. 2).

Some of the particulars of these engines may be put forward. The cylinder and cylinder head are cast in one piece. Very thorough cooling was obtained by this design, especially at the hottest parts of cylinder and head, as compared with the older design of the "Vulcanus" engine, where heavy flanges obstruct the passage of the water near the top of the combustion chamber. In the cylinder head are the customary apertures for the valves. The box-shaped piston is water cooled, for which purpose sea-water is introduced by special telescoping pipes without glands. After circulating there, it is led through another set of telescoping pipes back to the sea.

The cylinders are supported in threes in a cast-iron cylinder beam, the two beams being connected by an intermediate piece. The box-frame of the "Vulcanus" engine has been entirely discarded, being replaced by a set of steel columns that secure accessibility combined with strength and lightness. Cast-iron frames carry the guides. They are fixed below to the bedplate by studs and nuts, but at the top there is no rigid connection to the cylinder beam; strips of steel prevent any horizontal motion, but vertical motions are not prevented. This has the following object: At each combustion the internal forces tend to elongate the steel tie-rods. If the cylinder beam were fixed to the cast-iron columns the strain would go through these columns and bedplate, which parts would then require to be much heavier. Diagonals stiffen the engine in the horizontal direction and prevent vibration.

Special attention may be drawn to the trays underneath the pistons. These catch the oil that may drop from the cylinder wall and drops of water wasted from the telescoping pipes that bring the cooling water to and from the pistons. These trays, which are very effective, also serve to prevent the lubricating oil from splashing against the cylinder wall where it would otherwise be led by the pistons into the combustion chamber, causing a high consumption of lubricating oil.

In the "Emanuel Nobel" for the first time the waste gases were passed through a donkey boiler to give steam for the steering gear, whistle and ship heating. As this proved a success, Werkspoor followed this construction in all its later ships.

In 1912 Messrs. Sulzer Bros. put a set of two engines in the "Monte Penedo." They are two-stroke-cycle single-acting engines with four cylinders of 18.5-in. bore and 26.8-in. stroke and a speed of 160 r.p.m. They are remarkable for the absence of inlet and exhaust valves, the only valves in the cylinder heads being those for fuel injection and starting air.

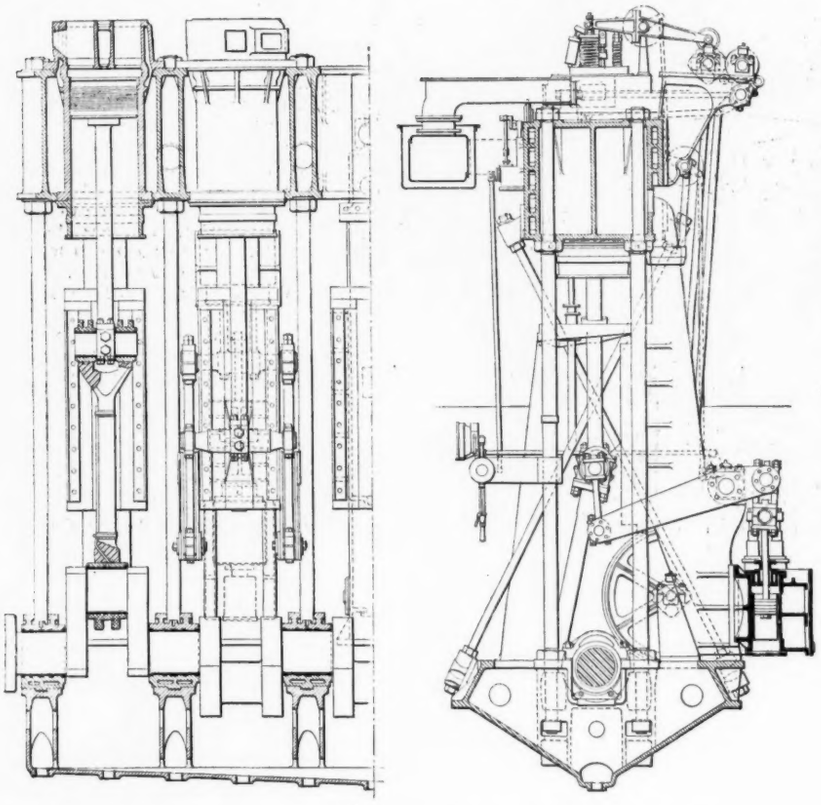


FIG. 2. WERKSPOOR MARINE DIESEL ENGINE OF 1,100 B.HP.

It makes a simple cylinder head, but involves complications in the cylinder wall. The exhaust takes place through openings in the cylinder wall forming a half-circle, whereas the other half of the periphery is taken by openings for scavenging air. Of those there are two rows, one above the other, and the communication between the air main and the top row of openings can be blocked by a double-seated valve. This arrangement serves to keep the scavenging air pipe closed at the beginning of the exhaust and then to keep it open after the exhaust is closed, thus preventing the exhaust gases from entering in the air line first and afterward securing an abundance of fresh air at the start of the compression.

The engine of the "Monte Penedo" is probably the most successful two-stroke-cycle marine motor at present in service. After some trouble with the pistons on the first voyage (the extension required to shut the exhaust and inlet ports worked loose), the construction was altered, and since then the motors have given full satisfaction. It must not be forgotten, however, that these engines were of the very best workmanship that can probably be found and they were operated by trained engineers.

An interesting engine in course of construction at Sulzer Bros.' is shown in Fig. 5. It is of 1,600 hp. and is intended for a tank ship. The resemblance of the lower part to standard steam engines must appeal to marine engineers.

At the close of 1912 the "Fordonian" was brought into service, and in 1913 the "Hagen," built by Messrs. Krupp. The latter is equipped with two single-acting two-stroke-cycle engines, each having cylinders of 18.9-in. bore and 31.5-in. stroke, running at 140 r.p.m.

In the same year the sister ship to the "Hagen," the "Loki," came into service. The air compressors of the "Hagen," which are worked separately by auxiliary Diesel engines of 275 hp. each, have given considerable trouble. After the first voyage to New York more than three months was needed for repairs and one of the compressors had to be renewed. The next voyage brought cracked pistons. The "Loki" also had to undergo repairs lasting a considerable time.

The "Wotan" with the Carels-type engines, mentioned before, also dates from 1913, but her running was stopped by the war.

The "Arthur von Gwinner" is fitted with two four-cylinder Junkers engines. The engines went through severe tests before being put into the ship, after which trials of considerable duration were made. The principle of the Junkers engine, reminding strongly of the Oechelhauser gas engine, has many attractions. The balancing of reciprocating forces, the absence of cylinder heads and stuffing boxes are advantages of great importance, but difficulties have arisen with the cylinders and the cooling of the pistons requires very difficult details. The ship had to repair very often before her working was stopped by the war.

To make this record of what has been done in marine Diesel motors as complete as possible, I include Fig. 3, showing a very light engine built for a small Netherlands gunboat. The two engines, each of

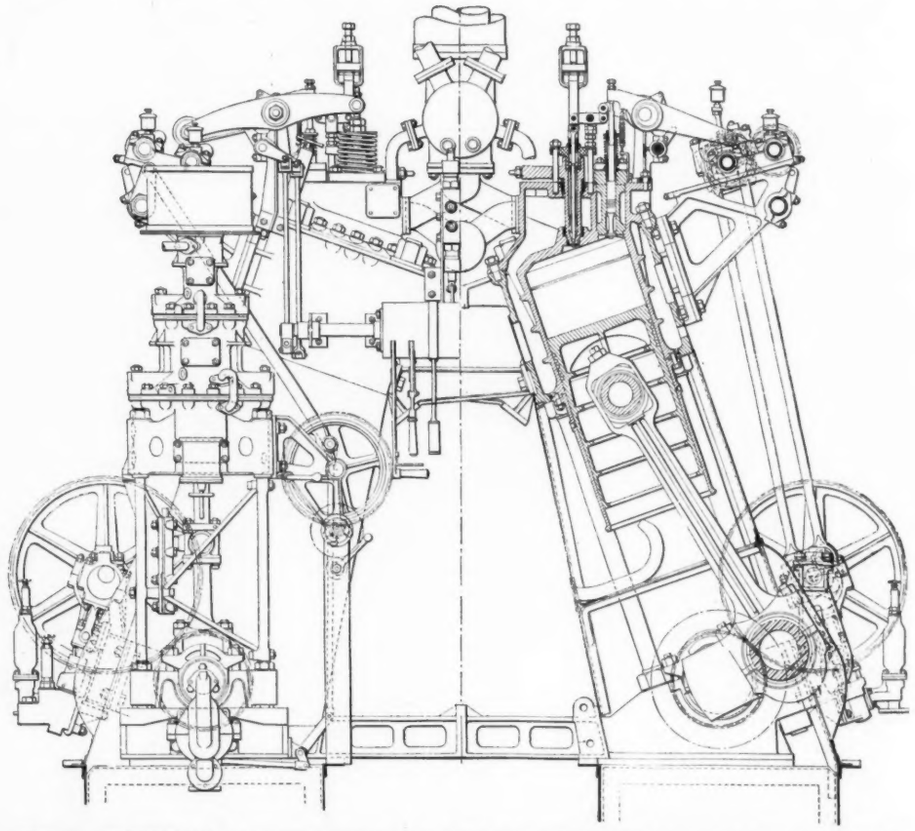


FIG. 3. SECTIONAL AND END VIEW OF 1,200 HP. INCLINED ENGINE FOR GUNBOAT

600 hp., are inclined toward the center of the ship to clear the armored deck. The result is an extremely stiff, accessible and light engine. Fig. 4 shows how easily a piston is dismounted. There is one cast-steel bedplate for the two motors. This bedplate, which is of very light scantlings, is connected

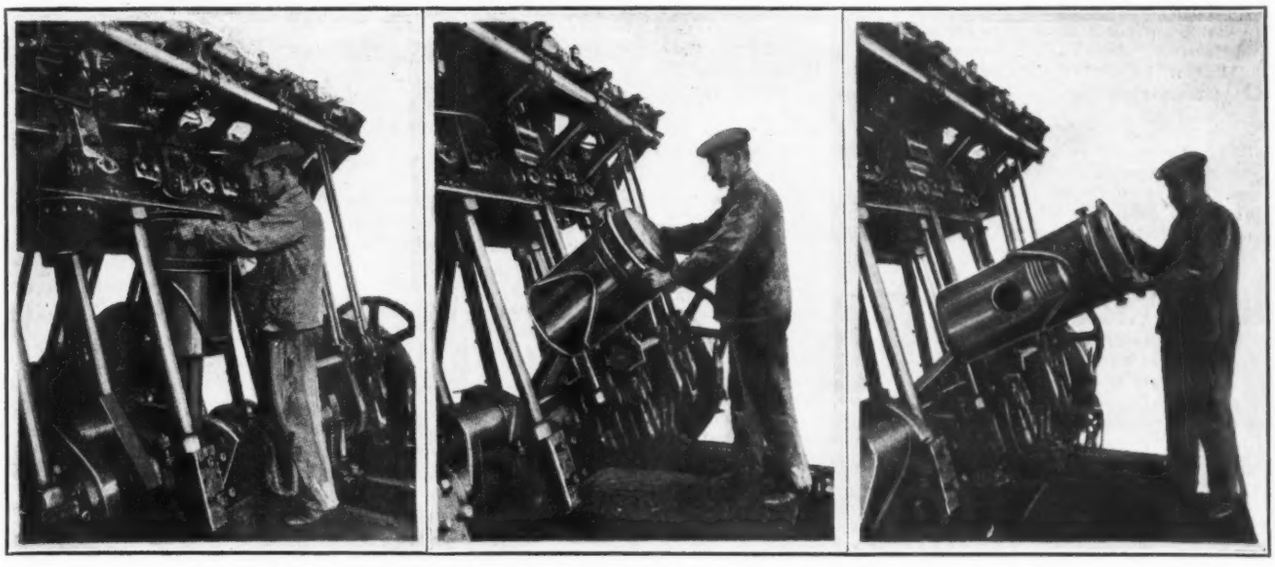


FIG. 4. SHOWING THE SUCCESSIVE OPERATIONS IN REMOVING PISTON

by steel columns to the two lines of six cylinders, which are united to one block by a bolted flange over the full length of the motor. The weight of this twin motor, including flywheel, up to the thrust bearing is 33 tons.

SOME LATER DIESEL-ENGINED SHIPS

In 1914 the increase of ships with Diesel motors is quite remarkable. Burmeister & Wain, of Copenhagen, delivered the following:

Name	Length	Beam	Depth	I.Hp.	No. of Screws
Pacific	362 ft.	51 ft. 3 in.	25 ft. 6 in.	2,000	2
Kronprince Gustaf Adolf	362 ft.	51 ft. 3 in.	25 ft. 6 in.	2,000	2
Fionia	410 ft.	53 ft.	38 ft.	4,000	2
Kronprincessin Margarete	362 ft.	51 ft. 3 in.	25 ft. 6 in.	2,000	2
Malakka	410 ft.	55 ft.	30 ft. 6 in.	3,000	2
Tonking	410 ft.	55 ft.	30 ft. 6 in.	3,000	2

Werkspoor, of Amsterdam, has delivered the engines for:

Name	Length	Beam	Depth	I.Hp.	No. of Screws
Elbruz	375 ft.	40 ft.	29 ft.	2,900	2
Ares	346 ft. 8 in.	46 ft. 6 in.	27 ft. 5 in.	2,300	2
Artemis	346 ft. 8 in.	46 ft. 6 in.	27 ft. 5 in.	2,300	2
Selene	346 ft. 8 in.	46 ft. 6 in.	27 ft. 5 in.	2,300	2
Hermes	346 ft. 8 in.	46 ft. 6 in.	27 ft. 5 in.	2,300	2
Jules Henry	305 ft.	40 ft.	23 ft.	1,350	2
Poseidon	185 ft.	30 ft. 6 in.	13 ft. 3 in.	450	1

The Polar Diesel Engine Co., of Stockholm, delivered the twin-screw two-stroke-cycle engines of about 800 hp. each for the "Sebastian," built at Dundee, but they did not give satisfaction. On the contrary, the troubles encountered were so great that after one voyage the engines were taken out.

In May, 1914, the "Arum," with English-built Polar-type engines, made her trials. After performing various short trips, she was sent to the Persian Gulf on her first long voyage, which was successful, according to reports.

The German motorship "Secundus" started her career in 1914. The owner, the Hamburg-American Line, now possesses two motor vessels, the "Christian X" and "Secundus." The former has four-stroke-cycle Burmeister & Wain engines and the latter two-stroke-cycle engines built by Blohm & Voss, of Hamburg. Each of these engines has four cylinders of 23.6-in. bore and 36.2-in. stroke, with a speed of 120 r.p.m., and develops 1,850 hp.

The scavenging air is produced by a pump worked by levers off one of the crossheads, the air entering the cylinders through four poppet valves in each cylinder head. The exhaust gases leave the cylinders through openings in the cylinder walls and a water-cooled pipe. The lower part of the engine resembles a steam engine, but forced lubrication is employed; the main crankshaft bearings are water-cooled. The pistons are cooled with fresh water.

The results obtained with a few nonreversible engines of 350-hp. driving propellers with reversible blades, by Werks-

poor, promise a great future for such engines for medium-sized crafts.

In designing a motor ship an important question is how to drive the deck machinery and the auxiliaries in the engine room. When plenty of money and a good personnel is available, the best system is to make electricity by Diesel motors and drive everything electrically. Where fuel to heat a boiler is expensive, this system is also the most economical in the long run. In first cost it is, however, the dearest, and a staff of engineers is required who can tackle a great many problems at once.

To save first cost and to keep the novelties in the ship within the smallest limits, the best plan is to have two donkey

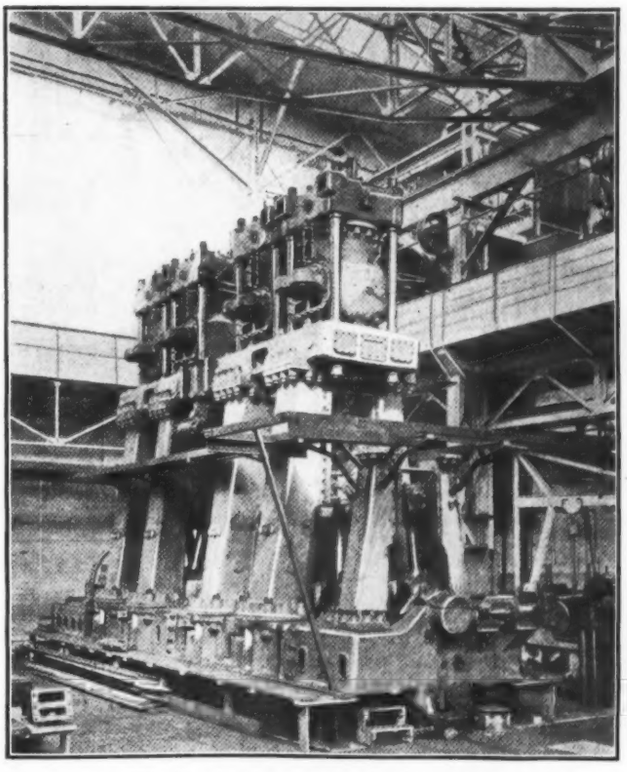


FIG. 5. 1,600-HP. DIESEL ON ERECTING FLOOR

boilers. Fire them either by coal or oil, depending on the price, and drive everything by steam, also the air compressor required to maneuver the main motor. When the ship runs several days continuously and the motor is of the four-stroke-cycle type, the waste gases can heat the donkey boiler, giving

plenty of steam for steering and for the whistle. The gain is about a ton of oil per day for ships of 6,000 tons. In short runs, or when the motor has to slow down often, this system cannot be applied. Driving the auxiliaries by compressed air has not proved a success, as the air compressors must be too large. In tank ships it is well to make the main cargo-discharging pump centrifugal and drive it by a Diesel motor. The same motor can then drive the air compressor for maneuvering. This system is slightly more expensive in first cost, but when the ship has to unload often it is cheaper in service than steam pumps.

SUITABLE FUELS FOR DIESEL ENGINES

The fuel question is one of great importance when discussing the merits of the marine Diesel engine. In the first years, the builders of these engines prescribed the use of solar oil, a distillate of petroleum having a specific gravity of not more than 0.88, a flashpoint of 80-100 deg. C. (180-212 deg. F.) and a lower calorific value of at least 10,000 cal. per kg. (18,000 B.t.u. per lb.).

Most of the Diesel engines up to the present have run on oil of approximately this composition, but heavier kinds have gradually come into use. The principal of these latter is the Tarakan oil, which has given complete satisfaction. The only inconvenience is that the starting of the motor is not always certain, so that some prefer to use solar oil when maneuvering. Some characteristic data regarding this oil are: Specific gravity, 0.955; flashpoint approximately 100 deg. C. (212 deg. F.); calorific value, 9,900 cal. per kg. (17,800 B.t.u. per lb.). It contains some water and asphaltum (1.4 per cent. insoluble in æther-alcohol).

That really all kinds of oil of the most widely different places of origin can be used will be seen from the following table, giving the characteristics of various kinds which have given good results in a Werkspoor stationary Diesel engine:

Name	Specific Gravity	Flash-point Deg. C.	Distillation Percentages To 300 Deg.	From 300 Deg. to 350 Deg.	Residue
Solar oil	0.880	99	79.0	17.0	4.0
Solar oil	0.857	95	10.4	50.0	39.6
Solar oil	0.856	92	82.0	14.0	4.0
Mixture Persian liquid fuel and Roumanian distillate	0.897	64	35.0	46.5	18.5
Solar oil	0.903	105	37.0	34.0	29.0
Solar oil	0.922	130	17.0	40.0	43.0
Solar oil	0.910	152	15.0	40.0	47.0
Residue	0.914	98	48.0	23.0	29.0
Residue	0.950	107	13.0	46.0	41.0
Masout (Batoum)	....	82	91.0	7.0	2.0
Heavy solar oil	0.913	138	36.0	57.0	7.0
Tarakan oil	0.955	103	41.0	24.0	35.0
Texas oil	0.905	123	30.0	40.0	30.0
California fuel oil	0.962	118	22.5	55.5	22.0
Egyptian residue	....	170	10.5	50.0	39.5
Trinidad crude oil	....	122	26.0	44.5	29.5
Mexican crude oil	....	105	26.0	33.0	41.0

For the heavier oils it was necessary to construct a special type of sprayer, which atomizes the oil more effectively, and to heat the oil in the tanks and the pipes to and from the fuel pump to diminish the high viscosity. Oils having a viscosity of more than 7 deg. Engler have to be heated before use. On the heavier oils the motor cannot be started, so that it is necessary to change to solar oil before stopping till the pipes and fuel pump are filled, so that on starting again the motor is ready.

Cleaning of Condenser Tubes

A municipal electric works made an experiment to clean condenser tubes of lime deposits by means of hydrochloric acid. Mixtures varying in strength from 1 to 2 to 1 to 10 were used for the metals under test; that is, brass, tin, copper, wrought iron and cast iron.

The action of the diluted acid on the bright surfaces of the parts to be cleaned was small, except with cast iron, which produced considerable quantities of hydrogen gas. Therefore, it is recommended to paint the cast-iron water chambers to protect them against the acid. By further trials the quantity of acid 1-to-5 solution that was needed to clean a single tube was ascertained. To keep the diluted acid in constant circulation in the horizontal type of condenser, the suction pipe of a small centrifugal pump was connected to the inlet branch of the condenser. The discharge pipe of the pump was connected to a cover plate of the condenser, to which was also connected a vent pipe that terminated under the surface of a water tank.

The condensers in question contained about 258 cu.ft. of water. They were charged for 3 hr. each with 3,792 lb. of hydrochloric acid of 22 deg. Baumé, and subjected for another 20 hr. to the action of the acid contained in the remaining solution until the formation of gas at the vent pipe had practically ceased. The fine mud in the tube was washed out by a strong stream of water, which discharged into the sewer. By analysis it was found that the deposit contained 83 per cent. of carbonated lime with small additions of organic and inorganic substances. The cost of the acid for dissolving the hard lime coating in this case for each condenser amounted to 0.2918c. per sq.ft. of cooling surface. The acid cost is based on a price of 51.64c. per hundred. The cooling surface was about 7,000 sq.ft.—"The Steamship."

First Government-Built Diesel Engines

One of the two Diesel engines built at the New York Navy Yard for the fuel ship "Maumee" has just undergone a series of tests on the erecting floor preparatory to its shipment to San Francisco, where the ship itself is being built. The tests included runs with different grades of oil, but the results will not be available until the official reports have been made.

The "Maumee" is one of two twin-screw fuel ships authorized by Congress in 1912, the sister ship, the "Kanawha," being fitted with two triple-expansion steam engines of 2,600 i.hp. each and oil-fired boilers. Since the vessels are identical except the propelling machinery and will be employed in the same kind of service, excellent opportunity will be afforded to compare performances. The propelling machinery of the Diesel-engined ship will occupy approximately the same space as the boilers and steam engines of the other, and the machinery weight will be slightly more. When the weight of fuel for the same cruising radius is included, however, the advantage will be with the Diesel engine.

When it was decided to install Diesel engines in the "Maumee," the Bureau of Steam Engineering, in order to gain a maximum of Diesel-engine experience in a minimum time, set about to obtain the manufacturing rights and a set of working plans from some company already engaged in that line of work, and to build the engines in one of the navy yards. The Navy Department therefore obtained bids from various companies at home and abroad and finally contracted with the Electric Boat Co., of Groton, Conn., American licensees of the Maschinenfabrik Augsburg-Nürnberg, of Germany. The Electric Boat Co., through a subsidiary company—the New London Ship and Engine Co., manufactures two-stroke-cycle single-acting Diesel engines of this type for submarines.

The contractor obtained the original designs and drawings from the home company, translated all figures from the metric to the English system, and supplied the Government with a set of retraced drawings in which only slight departures were made from the original design. These drawings were then checked with the originals at the navy yard. It would perhaps have been cheaper to build the engines from the original metric dimensions, as the translated drawings contained decimals to the thousandths of an inch and made the shop work rather slow and tedious. With the exception of some of the heavy forgings all parts were made in the navy yard.

The engines are of the single-acting two-stroke-cycle type, each rated at 2,500 hp. in six cylinders when turning over at 130 r.p.m. They are of A-frame construction with double crosshead guides, and the cylinder covers contain the fuel valves, scavenging air valves and starting air valves, the exhaust being through ports in the cylinder walls. Each cylinder has a separate fuel pump, and there is one fuel-supply pump for delivering the oil from the ship's bunker tank to the engine-supply tanks.

Besides the fuel pumps the following auxiliaries are driven from the main engine: Three high-pressure air compressors for fuel injection and for starting air; three scavenger compressors for cylinder scavenging; two salt-water pumps for jacket cooling; one fresh-water pump for piston cooling; one lubricating-oil pump for the thrust block, main bearings, crankpins and crossheads; two general-service water pumps; and twelve mechanical lubricators for the cylinders and minor lubrication. A governor and a revolution counter are also fitted. Steam for heating, deck engines, etc., will be furnished by two small oil-fired boilers.

Friction in an Engine, as determined by three sets of tests, is distributed approximately as follows:

Main bearings	47.1%	35.4	35.0
Piston and rod	32.9	25.0	21.0
Crankpin	6.8	5.1	13.0
Crosshead pin	5.4	4.1	
Valve and rod	2.5	26.4	22.0
Eccentric strap	5.3	4.0	
Link and eccentric	0.0	0.0	9.0
	100.	100.	100.